Weather-Related Disasters, Rural Livelihoods and Off-Farm Self-Employment

Three essays in Development Microeconomics

Doctoral Thesis

to acquire the academic degree of
doctor rerum politicarum
(Doctor of Economics and Management Science)
submitted to the
School of Business and Economics of
Humboldt-Universität zu Berlin
by
MA Anna Katharina Lehmann-Uschner, né Lehmann

President of the Humboldt-Universität zu Berlin:
Prof. Dr.-Ing. habil. Dr. Sabine Kunst
Dean of the School of Business and Economics:
Prof. Dr. Daniel Klapper

Reviewers:
1. Prof. Dr. Lukas Menkhoff
(Humboldt-Universität zu Berlin, Germany)
2. Ass. Prof. Nathan Fiala, PhD
(University of Connecticut, United States of America)

Date of Colloquium: April 16, 2020

Abstract

Anthropogenic climate change is a global challenge, but its effects are felt disproportionally in developing countries. As such, poor people incur significantly higher disaster-induced losses due to higher shock exposure and vulnerability as well as fewer resources for adaptation and recovery.

Despite the far-reaching impacts of climate change on households in developing countries and the predicted aggravation of climate change outcomes, there is still little research focusing on the link between them. In particular, the long-term consequences of weather-related disasters on the livelihood of poor households are not well understood.

This thesis aims to help our understanding of the complex links between changing climatic conditions and development for affected households. It sheds light on three different stages of the climate-change – development nexus. Chapter 2 is concerned with the immediate consequences of an extreme weather event for food security, focusing on dietary quantity and quality. It analyses to what extent food self-provisioning can help reduce the income elasticity of consumption and shows the negative effects of a weather-related disaster on dietary quality. Chapter 3 looks at shock persistence. Based on a theoretical model, it provides robust evidence for negative growth effects of a one-off extreme weather event, in addition to the immediate losses caused. It also demonstrates that the effects of extreme weather events are stronger than those of other household-level shocks. Chapter 4 analyses the income-earning potential in non-agricultural micro self-employment. It provides robust evidence for the existence of returns to education even in a context of petty self-employment, highlighting different transmission channels. Put together, these results call for policy action addressing all stages of the climate change – development nexus: Immediate disaster relief as well as longer-term mitigation and adaptation efforts.

Zusammenfassung

Der Klimawandel ist eine globale Herausforderung, aber seine Auswirkungen sind besonders stark in Entwicklungsländern zu spüren. So erleiden arme Menschen deutlich höhere Verluste, weil sie Extremereignissen stärker ausgesetzt sind und weniger Ressourcen für Anpassung und Schockbewältigung haben.

Trotz der weitreichenden Auswirkungen des Klimawandels auf Haushalte in Entwicklungsländern ist die aktuelle Forschung zum Zusammenhang zwischen Klimawandel, Armut und Entwicklung begrenzt. Insbesondere die langfristigen Folgen von Wetterextremen für betroffene Haushalte sind wenig erforscht.

Diese Arbeit soll dazu beitragen, die komplexen Zusammenhänge zwischen veränderten klimatischen Bedingungen und Entwicklung auf Haushaltsebene besser zu verstehen. Kapitel 2 befasst sich mit den unmittelbaren Folgen eines extremen Wetterereignisses für die Ernährungssicherheit, wobei Nahrungsmenge und -qualität untersucht werden. Es analysiert, inwieweit die Selbstversorgung mit Nahrungsmitteln die Einkommenselastizität für Ernährung verringern kann und zeigt die negativen Folgen eines Wetterschocks auf die Ernährungsqualität auf. Kapitel 3 befasst sich mit der Schockpersistenz. Basierend auf einem theoretischen Modell zeigt es negative Wachstumseffekte eines einmaligen extremen Wetterereignisses, zusätzlich zu den unmittelbaren Verlusten. Es zeigt auch, dass die Folgen von extremen Wetterereignissen stärker sind als die von anderen Schocks auf Haushaltsebene. Kapitel 4 analysiert das Einkommenspotenzial in der nicht-landwirtschaftlichen Kleinstselbstständigkeit. Selbst in diesem Kontext unvollständiger Märkte existieren robuste Bildungsrenditen. Das Kapitel zeigt außerdem verschiedene Übertragungskanäle auf. Zusammengenommen fordern diese Ergebnisse politische Maßnahmen, die den Nexus Klimawandel - Entwicklung auf unterschiedlichen Ebenen adressieren: Unmittelbare Katastrophenhilfe sowie längerfristige Anpassungsunterstützungen.

Acknowledgements

Writing this dissertation was a long journey and I am highly grateful to all the people who supported me during the process. First I want to thank my scientific mentors. In particular, I would like to thank my first supervisor Lukas Menkhoff for all his support, input and honest feedback. I also thank Nathan Fiala for taking over the responsibility as second supervisor. A special thank you goes to Kati Krähnert, my former head-of-department and co-author. Thank you for giving me the possibility to do research in this exciting Mongolia project and thank you for allowing me to take over great responsibilities right from the beginning. Writing the papers together with you was a great pleasure and I learned a lot from your drafting skills. Furthermore, I am particularly grateful to Jean-Louis Arcand for sparking the passion for development economics and econometrics. Your lectures were absolutely inspiring! And I also want to thank Krisztina Kis-Katos and Lore Vandewalle for your time and feedback, both on the content of my papers as well as on life in academia.

I also want to thank the DIW for giving me the opportunity to pursue my PhD and supporting me until the completion of my PhD even after several departmental changes. The research in Mongolia was funded by the German Federal Ministry of Education and Research, funding line "Economics of Climate Change", research grant 01LA1126A. The data collection in Uganda was supported by the Agricultural and Rural Finance Program (AGRUFIN) of the *Gesellschaft für internationale Zusammenarbeit (GIZ)* in Uganda.

Second, I am grateful for all the support I received from my colleagues at the Development and Security Department at the DIW. It was a great pleasure sharing an office with you, Veronika Bertram-Hümmer. Friederike Lenel, thank you for your time and the highly valuable discussions, your constructive feedback on my work and for being an excellent mentor and role-model scientist. Thank you also to all members of my Graduate Center cohort for endless rounds of football, inspiring discussions and many fun nights out. I would not have survived the first year without you and you made PhD-life a very agreeable time. And thank you to all members of the organizing team of the Development Economics Network Berlin. I am very proud we created such an inspiring network and continue

to organize so many exciting activities. Thank you also for constructive discussions of my research. This exchange is a continuous source of motivation.

Finally, I would not have been able to complete this thesis without the unconditional support of my family and friends. Thank you for believing in me, for encouraging me to pursue what I am passionate about and simply for being there for me whenever I needed you. Friedemann, thank you for your unconditional love and support. And thank you for having my back whenever a deadline was coming up (and there were many). Leonore and Benjamin, thank you for constantly reminding me that - despite all my passion for doing research - work should never be the only thing in life. You are the best kids I could wish for.

Contents

List of Figures

List of Tables

Abbreviations

2SLS	Two-stages least squares
AE	Adult Equivalent
AIC	Akaike Information Criterion
CDF	Cumulative Distribution Function
ECMWF	European Centre for Medium-Range Weather Forecasts
FAO	Food and Agriculture Organization of the United Nations
HH	Household
HIES	Household Income and Expenditure Survey
IFAD	International Fund for Agricultural Development
IFRC	International Federation of Red Cross and Red Crescent Societies
IRT	Item Response Theory
IV	Instrumental Variable
LS	Livestock
LSMS	Living Standard Measurement Survey
MDE	Minimum detectable effect
MRCS	Mongolian Red Cross Society
NGO	Non-governmental organization
NSO	National Statistical Office of Mongolia
OLS	Ordinary least-squares
PCA	Principal component analysis
SD	Standard deviation
UGX	Ugandan Shilling
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UNICEF	United Nations Children's Fund
USD	US Dollar
WHO	World Health Organization

Chapter 1

Introduction

1.1 Motivation

Anthropogenic climate change is a global challenge and pressing policy issue. Impacts of the increasing average global temperature, the acidification of oceans or a rising sea-level are observed across all continents (Pachauri et al., 2014). Yet, the effects of climate change are felt disproportionally in developing countries. This is caused primarily by their geographic *exposure*, the larger shock *vulnerability* and fewer political and financial *resources* for adaptation and recovery (World Bank, 2010). Over the past two decades, weather-related disasters claimed more than half a million lives and affected more than 4 billion people worldwide, the vast majority of whom lived in developing countries (United Nations Office for Disaster Risk Reduction, 2015). And even within a given country, it is again the poor who are disproportionally affected. Winsemius et al. (2018) find that poor people are generally more exposed to droughts, higher temperatures, or urban river floodings. In addition, given the nature of poor households' livelihoods, in particular their dependence on agriculture, and the structure of their asset base, poor people lose more than twice the amount of their wealth compared to the nonpoor when hit by a disaster (Hallegatte et al., 2017). Finally, recovery after a shock is much harder as affected households in developing countries typically only receive limited support: Developing country governments often lack the political and financial means for adequate disaster relief or pre-shock adaptation to the changing climatic conditions and informal insurance arrangements tend to fail in the face of covariate disasters. Put together, climate change poses new threats to development. It threatens in particular the eradication of extreme poverty (Hallegatte et al., 2015). And this situation is expected to worsen further in the future as extreme weather events are predicted to increase in frequency and intensity due to climate change (World Bank, 2010; Seneviratne et al., 2012).

The link between climate change and development - poverty in particular - has many facets (Hallegatte et al., 2015). One of the most prevalent threats is the negative effect of climate change on food security. After years of continuous success in the fight against global hunger, the prevalence of under- and malnutrition is rising again since 2014 (FAO, IFAD, UNICEF, WFP and WHO, 2018). Many households in developing countries depend heavily on agrarian systems for their livelihood. Hence, "climate variability puts all aspects of food security at risk: the amount of food produced, people's access to it, people's ability to absorb nutrients and the safety of the food itself" (FAO, IFAD, UNICEF, WFP and WHO, 2018). And the increasing frequency with which extreme events occur makes it harder for the entire ecosystem, and agricultural plantations or livestock in particular, to recover. In turn, households become again more dependent on external support.

In addition, climate change magnifies threats to health, especially for poor people (Costello et al., 2009). This is even more of a concern as poor health contributes to poverty (Bor et al., 2017). Also education outcomes worsen when households are exposed to extreme weather events or increased climate variability. Several studies found that households take their children out of school in order to cope with extreme events (Hanna and Oliva, 2016). And the irreversible effects on education and health can reinforce the intergenerational transmission of poverty.

Finally, the negative development consequences of changing climatic conditions can also manifest themselves in the form of adverse impacts on the households' livelihood, in particular their asset base. These effects on household well-being are often larger than the immediate destruction of assets (Hallegatte et al., 2017): Individual recovery is hampered as disasters dampen overall economic growth and recurrent risks reduce incentives to invest (Hallegatte et al., 2017).

Despite these far-reaching impacts of climate change on households in developing countries and the predicted aggravation of climate change outcomes in the future, climate change and poverty (or development in general) are until now primarily discussed as two distinct problems (Hertel and Rosch, 2010). There is little research focussing on the link between them. In particular, the long-term consequences of weather-related disasters on the livelihood of poor households are not well understood. Yet, reaching the sustainable development goals of fighting global undernutrition and eradicating extreme poverty can only be successful based on a thorough understanding of the various links between changing climatic conditions and development.

This thesis aims to help our understanding of the complex links between changing climatic conditions and development for affected households. It sheds light on three different stages of the climate-change – development nexus. Chapter 2 is concerned with the immediate consequences of an extreme weather event on food (in)security and "hidden hunger" in particular - the inadequate intake of micronutrients (in addition to energy intake). It analyses to what extent food self-provisioning can help reduce the income elasticity of consumption and shows the negative effects of a weather-related disaster on dietary quality. Chapter 3 looks at shock persistence. Based on a theoretical model, it provides robust evidence for negative growth effects of a one-off extreme weather event, in addition to the immediate losses caused. It thus shows how shock effects get perpetuated into the future and are palpable even several years after the actual shock occurred. It also demonstrates that the effects of extreme weather events are stronger than those of other household-level shocks and shows that severe shock exposure is a strong predictor for abandoning the herding economy. Chapter 4 then looks at opportunities outside agriculture. With continuing threats to their agrarian livelihood due to changing climatic conditions, many households look for alternative income-earning strategies. In the absence of a market-clearing amount of adequate employment opportunities, many poor people start working on their own account (Quatraro and Vivarelli, 2014). The majority of these own-account workers work for themselves and earn little (Gindling and Newhouse, 2014). Chapter 4 provides robust evidence for the existence of returns to education even in this context of petty self-employment. Put together, these results call for policy action addressing all stages of the climate change – development interaction: Disaster relief as immediate response to an extreme weather event that reaches all in need, longer-term support to mitigate adverse growth effects, and efforts focused on adaptation to the changing climatic conditions, including improvements of households' prospects outside agriculture to which investments in education infrastructure might contribute.

1.2 Research Approach

The analyses in this thesis build on different microeconometric techniques that are applied to three distinct household-level data sources. Chapter 2 and 3 focus both on Mongolia but use different data. The former employs the Household Income and Expenditure Survey/Living Standards Measurement Survey (HIES/LSMS), a dataset covering 3,308 households representative for the entire Mongolian population. It was collected by the National Statistical Office of Mongolia and the World Bank in 2002/2003. The latter analysis is based on the Coping With Shocks in Mongolia Survey, an original panel survey of 1,768 households in three provinces in Western Mongolia with three yearly waves collected between 2012 and 2015 by the German Institute for Economic Research in collaboration with the National Statistical Office of Mongolia. Developing the questionnaire, supporting the data collection and preparing the raw data for further use was part of my research work done in preparation of the analyses presented in this thesis. The survey data are complemented with livestock data from the annual Mongolia Livestock Census, weather data from the European Centre for Medium-Range Weather Forecasts and data on emergency aid compiled by the Mongolian Red Cross Society.

Mongolia is a particularly interesting setting to study the link between climate change and development outcomes. Extremely harsh winters - referred to as *dzud* in Mongolian - lead to mass livestock mortality. Since *dzuds* are caused by various climatic conditions, often by a combination of several events (Batima, 2006), households can hardly predict their occurrence (Murphy, 2011). While *dzuds* are not a new phenomenon, their intensity and frequency has increased dramatically over the past two decades. At the same time, around 19 percent of the Mongolian population are dependent on livestock for their livelihood (National Statistical Office of Mongolia, 2013). *Dzuds* therefore constitute a major cause for rural poverty (Sternberg, 2010). In addition, with more than one third of the earth's land surface being arid or semi-arid areas in which livestock grazing constitutes the only viable food production strategy (Tchakerian, 2015), the findings discussed in this thesis have important implications for other regions as well.

The research in the last chapter is based on data collected in Uganda by the German Institute for Economic Research in collaboration with the Mountains of the Moon University and the German Technical Cooperation (*GIZ*). For this project I was responsible for the questionnaire development and supported the data cleaning.

Uganda presents an economically meaningful research setting to analyse the returns to education in a context of petty self-employment as it exemplifies well the economic situation in many African countries. Results from the presented analysis therefore provide interesting insights for other countries as well. Self-employment is omnipresent in most Sub-Saharan African economies: It accounts for more than three quarters of total employment, the majority of it being petty self-employment (Filmer and Fox, 2014). Economic growth has been largely jobless over the past years as the positive economic developments at the country-level were not matched with increased employment opportunities (Kiranda et al., 2017). This situation is unlikely to change soon and petty self-employment thus predicted to persist (Filmer and Fox, 2014). This calls for more research on how skills could benefit the returns from this form of occupation.

1.3 Dissertation Outline

The main part of the dissertation consists of three chapters, each of which is a separate research paper. Chapters 2 and 3 are joint work with Kati Krähnert, chapter 4 is single-authored. The following section provides an overview over the central question and research findings of each chapter and presents their contributions to the existing literature.

1.3.1 Chapter 2 - Research question and findings

Chapter 2 investigates the role of food self-provisioning for the intake of several macro- and micronutrients of households in Mongolia. Today, a quarter of children worldwide are stunted, a sign of chronic malnutrition (De Onis et al., 2012). Furthermore, micronutrient deficiencies, often termed "hidden hunger", continue to be a central nutritional and developmental problem. Worldwide, over 2 billion people suffer from micronutrient deficiencies (Von Grebmer et al., 2014), which has important individual and societal consequences. Inadequate intake of key nutrients, particularly during early childhood, can impair subsequent physical, cognitive and behavioural development (for ex. Arlappa et al., 2011; Victora et al., 2008), which in turn may cause lower productivity and foregone GDP (Shekar et al., 2006).

We analyse nutritional outcomes within and across urban wage employees, rural households with small herds, and pastoralists with large herds. Using exceptionally rich data on food consumption - consumption diaries covering more than 90 food items were filled out by each sample household over a 12 week period - we show that food self-provisioning significantly affects dietary quality and quantity. Farming food crops improves the nutrient intake. In contrast, animal husbandry increases the intake of calories and nutrients from animal sources, while it decreases the intake of carbohydrates and nutrients from vegetal sources. This finding suggests household-specific market failures due to remoteness exist. Last, exposure to a weather shock does not affect households' calorie intake for the full sample but has a negative effect on the intake of several macro- and micronutrients for small-scale herding households dependent on food self-provisioning.[1]

1.3.2 Chapter 2 - Contributions

This chapter builds on and adds to the literature focusing on the determinants of nutrition demand in developing countries. While most existing studies look at caloric intake only, an emerging field of research is concerned with the inadequate intake of several micro- and macronutrients. Even though households may maintain their calories consumption when facing higher or lower income, this relationship provides little information on how nutritional quality responds to changes in income. Overall, results regarding the income elasticity for calories as well as other micro- and macro nutrients are very diverse across empirical contexts (see Skoufias et al., 2009, for a summary). A related, but rather heterogeneous field of research tackles the link between nutrition and agricultural production at the household level. Yet, robust empirical evidence on this link is still scarce (Carletto et al., 2015; Ruel et al., 2013).

Chapter 2 contributes to this literature in two ways. First, most existing studies capture food self-provisioning with rather coarse (indicator variables for food self-provisioning) measures. These coarse measures have two potential drawbacks: On the one hand, they render it hard to grasp the exact contribution of food self-provisioning to nutrition. On the other, it is difficult to pinpoint whether the effect works through an income channel or immediately through the consumption of self-produced foods. The rich HIES/LSMS dataset allows us to account precisely for the extent of food subsistence and to test whether food self-provisioning affects nutrient wealth elasticities.

Second, there is little evidence to date on the effect of shocks - and extreme weather events in particular - on food consumption. We provide robust evidence that exposure to the severe 2001/02 winter does not significantly affect household overall energy intake for the full sample. Yet, there is a significant reduction in micro- and macronutrient consumption for small-scale herders

[1] Households count as dependent on food self-provisioning if more than 1/3 of the calories consumed stem from own production.

who are dependent on food self-provisioning. We do not find such effects for large-scale herders or households with only little food self-provisioning. This implies that households who are already at the subsistence level risk being unable to meet basic consumption needs in the aftermath of a weather-related disaster.

1.3.3 Chapter 3 - Research question and findings

Chapter 3 analyzes to what extent an extreme weather event can have persistent effects on household-level asset growth. Extreme weather events, such as storms, floods, and cold waves often cause immediate asset losses, thus reducing household welfare. In addition, the loss of productive assets may reduce a household's future consumption and income-earning potential and, thus, its future welfare. Furthermore, if the effects of extreme weather events go beyond immediate impacts on current asset levels and also affect asset growth rates, shock effects may be perpetuated.

Our focus is on the effect of a particularly severe winter disaster (*dzud*) on post-shock livestock accumulation among pastoralists in Mongolia. Using a Hausman-Taylor estimator, we show that the extreme event has a significant, negative, economically large, and persistent effect on households' asset growth rates even 2-5 years after the disaster occurred. Households seek to mitigate the shock effect by reducing their livestock offtake. This effort is counteracted by a large, negative, and persistent shock effect on livestock fertility. In addition, the intensity of the extreme weather event is a strong predictor for abandoning the herding economy, resulting in lower overall welfare. Our findings suggest that most households are unable to fully offset the effects of the weather disaster through their own coping behavior.

1.3.4 Chapter 3 - Contributions

So far, little is known about the persistence of the effects of extreme weather events on households in developing countries. The existing literature on growth effects of extreme weather events and other natural disasters is narrow and focuses mainly on the country level (Cavallo et al., 2013; Felbermayr and

Gröschl, 2014; Strobl, 2012; Kellenberg and Mobarak, 2011; Loayza et al., 2012). The few existing studies taking a household-level approach document that exposure to extreme weather events and other natural disasters adversely impacts human capital accumulation, child health, remittances, and income (Caruso and Miller, 2015; Gignoux and Menéndez, 2016; Groppo and Kraehnert, 2016, 2017). However, the impact of these events on household-level growth rates – and, in particular, asset growth – is not well understood. This gap in research is surprising, given the importance of assets in shaping households' long-term welfare dynamics (Dercon et al., 2012; Carter and Barrett, 2006; Sahn and Stifel, 2003).

Chapter 3 advances the existing household-level literature on growth in developing countries in several ways. Shock persistence is typically not accounted for in standard empirical growth models, particularly at the household level, where shocks are generally only seen as a temporary setback (Dercon, 2004; Barrett et al., 2006). We add to this literature by showing both theoretically and empirically how a one-off shock can have persistent effects on household asset dynamics even years after the shock occurred. Moreover, we provide novel insights into how households reconstruct their asset base in the aftermath of a shock. So far, only a few studies unravel what strategies households apply to recover from shock-induced losses.

Moreover, this study contributes to the literature on asset-based poverty traps (Carter and Barrett, 2006; Barrett and Carter, 2013). This literature assumes that a locally positive relationship between asset holdings and marginal returns to assets exists, which implies multiple asset equilibria toward which households converge in the long term. Yet, empirical evidence for such multiple equilibria is scarce (Kraay and McKenzie, 2014). Furthermore, the small number of studies within this literature specifically exploring how shocks influence household asset dynamics are often beset with endogeneity problems caused by the nature of the shock (Carter et al., 2007; Giesbert and Schindler, 2012; Quisumbing and Baulch, 2013). In addition, most asset-based poverty traps studies mainly rely on nonparametric approaches (Carter and Barrett, 2006; Barrett and Carter, 2013; Naschold, 2012), thus leaving the underlying processes and the role of household heterogeneity unscrutinized. This chapter expands this literature by documenting how household asset dynamics can be persistently shaped by a shock without requiring a framework of bifurcating asset dynamics. In addition, our focus on an extremely severe covariate shock that occurred over a short time period, immediately destroying household assets, allows for a straightforward identification of the shock effects, posing few endogeneity concerns. Moreover, the importance of livestock in the pastoralist economy as well as the ease with which it is observed greatly reduces measurement error problems inherent in studies that bundle various types of assets into one common index (Naschold, 2012; McKay and Perge, 2013).

Lastly, chapter 3 contributes to the literature on welfare dynamics among pastoralists (e.g. Bertram-Huemmer and Kraehnert, 2017; McPeak and Barrett, 2001; Toth, 2014). Most existing studies are constrained by small sample sizes, often less than 100 households (Verpoorten, 2009; Lybbert et al., 2004; McPeak, 2006). In contrast, our analysis builds on a sample of more than 850 pastoralist households that are representative of the population in the survey area. Moreover, data on livestock holdings is recorded from each household in three annual panel survey interviews in the post-shock period, while pre-shock herd size is asked retrospectively from households. This unique data allows us to observe households' asset growth over a medium-term time horizon.

1.3.5 Chapter 4 - Research question and findings

Chapter 4 investigates returns to education for the self-employed when the decision to become self-employed is driven by economic necessity rather than a voluntary choice. The research on the returns to education has so far focused mainly on outcomes in terms of wage income. This bypasses the reality in many developing countries in which the majority of the workforce is engaged in – mostly petty – self-employment. So far, little is known about the potential returns to education for these non-agricultural self-employed in developing countries. This paper seeks to address this gap in the literature. Using a unique sample of 1,048 market vendors in Western Uganda, I provide evidence of 7 percent returns to education even within a setting in which sectoral or occupational choices are constrained. Welch's (1970) allocative and productive efficiency gains as well as social capital increases are presented as potential mechanisms underlying the observed returns. I address endogeneity by a synthetic instrumental variable approach proposed by Lewbel (2012), additionally using the universal primary education reform. Furthermore, I find no differential returns to schooling by education level. Finally, to avoid biased estimates through confounding factors, I use the double machine learning approach proposed by Chernozhukov et al. (2018) to select additional control variables. Estimates on the returns to education are in line with the baseline specification.

1.3.6 Chapter 4 - Contributions

So far, research on the effect of education on entrepreneurship is still disappointing, despite the large body of evidence on returns for wage employment (Van der Sluis et al., 2005). Chapter 4 contributes to the existing literature on the returns to schooling for the self-employed in developing countries in two important ways. First, it provides robust evidence for the existence of the returns to education in a static labour market setting with very limited options for occupational choice. It thus extends the existing literature in which returns to education are mainly discussed as sorting device between wage- and self-employment or as enabling individuals to profit from dynamic opportunities (see for ex. Vijverberg, 1986). In particular, Van der Sluis et al. (2005) shows that the more educated workers typically end up in wage employment. This effect is stronger for women and in least-developed countries where agriculture is more dominant. In contrast, the present paper finds evidence for significant returns to education among a group of own-account workers that entered self-employment mainly due to labour market push factors. This is remarkable given that the returns to education have been found to be larger for opportunity compared to necessity entrepreneurs (Fossen and Büttner, 2013).

Second, chapter 4 enhances our understanding of where these returns even within a narrowly defined type of occupation - own-account market-vending -

come from. Understanding these mechanisms is important to generalize findings from this paper to contexts other than the specific one studied here. In particular, this study shows that education is relevant for different aspects of self-employment. Schooling can increase the actual labour productivity through both general education effects and enhanced business-specific knowledge. In addition, it is associated with increases in earnings from non-agricultural self-employment as it raises the probability to select into a more profitable category or type of self-employment. Social network effects also improve returns.

Chapter 2

Food Intake and the Role of Food Self-Provisioning[1]

with:
Kati Krähnert

Abstract

This chapter investigates the role of food self-provisioning for the intake of nutrients of households in Mongolia. We analyse nutritional outcomes within and across urban wage employees, rural households with small herds, and pastoralists with large herds. Food self-provisioning significantly affects dietary quality and quantity. Farming food crops improves the nutrient intake. In contrast, animal husbandry increases the intake of calories and nutrients from animal sources, while it decreases the intake of carbohydrates and nutrients from vegetal sources. This finding suggests household-specific market failures due to remoteness exist. Last, exposure to a weather shock does not affect households' calorie intake for the full sample but has a negative effect on the intake of several macro- and micronutrients for the households dependent on food self-provisioning.
JEL codes: O12, I32

[1]This is an accepted manuscript of an article published by Taylor and Francis in the *The Journal of Development Studies* on 19 Sep 2016, available online https://doi.org/10.1080/00220388.2016.1228881

2.1 Introduction

Since the early 2000s, major achievements in the fight against global hunger have been made: the number of people suffering from hunger dropped from 927 million to 795 million between 2006 and 2015 (FAO, IFAD and WFP, 2015). Yet, a quarter of children worldwide are stunted, a sign of chronic malnutrition (De Onis et al., 2012). Furthermore, micronutrient deficiencies, often termed hidden hunger, continue to be a central nutritional and developmental problem. Worldwide, over 2 billion people suffer from micronutrient deficiencies (Von Grebmer et al., 2014), which has important individual and societal consequences. Inadequate intake of key nutrients, particularly during early childhood, can impair subsequent physical, cognitive and behavioural development (for ex. Arlappa et al., 2011; Victora et al., 2008), which in turn may cause lower productivity and foregone GDP Shekar et al. (2006).

In this article, we investigate the role of food self-provisioning for the macro- and micro-nutrient intake of Mongolian households. The context of Mongolia is a particularly interesting case for studying nutrition as the Mongolian population engage in strikingly diverse livelihoods. On the one hand, there are herders who produce a large share of their own food. The group of herding households comprises both (semi-) nomadic pastoralists who use animal husbandry as their main source of sustenance and households tending a smaller number of animals complementary to other income activities. On the other hand, there are urban wage earners who buy most of their food from markets. The three livelihood groups also face different degrees of market imperfections in food and agricultural output markets that range from being close to perfect in urban areas to completely missing for at least some food groups in remote rural areas.

Our article analyses nutritional outcomes of households following three different types of livelihoods that derive food from different sources. We first explore nutrient wealth elasticities across and within livelihood groups. Our analysis then investigates the role of food self-provisioning by accounting for the share of calories produced by animal husbandry activities within the household and, separately, for the household's farming activities. Lastly, we explore the impact of one extreme weather event on nutrient intake and food self-provisioning. Our focus is on the extremely harsh 2001/02 winter – called *dzud* in Mongolian – that caused the death of about 11 percent of the national livestock. The outcome measures of interest are the daily quantities of calories, carbohydrates, fat (animal and vegetal), proteins (animal and vegetal), vitamin A, and iron consumed per adult equivalent. The database for our analyses is the nationally representative Household Income and Expenditure Survey/Living Standards Measurements Survey (HIES/LSMS), a household survey implemented in 2002/03. The survey provides exceptionally rich data on food consumption: consumption diaries covering more than 90 food items were filled out by each sample household over a 12 week period.

Our article builds on and adds to the literature focusing on the determinants of nutrition demand in developing countries. Early studies in this field primarily tested empirically whether households' consumption of calories increases when economic conditions improve, irrespective of whether income is generated in agriculture or other economic sectors. Here, the common approach is to estimate the income elasticity of calorie consumption, with consumption expenditures often used as a proxy for income (see Strauss and Thomas, 1995, for a review of early studies). An emerging field of research focusses on the intake of micro- and macronutrients. This shift in focus is due to the fact that even though households may maintain their calorie consumption when facing higher or lower income, this relationship provides little information on how the consumption of nutrients and dietary diversity responds to changes in income. Overall, results regarding the income elasticity for calories as well as other micro- and macronutrients are very diverse across empirical contexts (see Skoufias et al., 2009, for a summary).

A related, but rather heterogeneous field of research tackles the link between nutrition and agricultural production at the household level. Recent reviews of the literature conclude that robust empirical evidence on this link is still scarce (Carletto et al., 2015; Ruel et al., 2013). Within this field, a small number of studies explore the role of food self-provisioning through the household's own agricultural activities for nutrition. For instance, Muller (2009) analyses the role of food crop production in rural Rwanda in the mid-1980s, a context in which rural markets work imperfectly and rural households are close to autarkic in important staple foods. Muller finds evidence for a strong relationship between the value of the harvest of the main food crops and the body mass index of adults. Moreover, several studies in a special issue of the Journal of Development Studies (Carletto et al., 2015) explore the role of food self-production on various outcomes. Azzarri et al. (2015), for example, find that the ownership of different livestock species among poor households in rural Uganda affects their consumption of animal sourced foods, thus helping improve nutritional outcomes. Hoddinott et al. (2015) analyse the impact of household agricultural production on nutritional outcomes in rural Ethiopia, finding that cow ownership increases milk consumption and reduces child stunting, which the authors attribute to market imperfections in the dairy sector. Kumar et al. (2015) investigate the link between agricultural production diversity and dietary diversity at the household level in Zambia, finding a strong positive association between the two.

Our article contributes to this literature in two ways. First, most existing studies capture food self-provisioning with rather coarse measures, such as an indicator variable for cow ownership (Hoddinott et al., 2015; Slavchevska, 2015), an indicator variable for the ownership of a garden (Gibson and Rozelle, 2002), an indicator variable for urban farming or livestock activities (Tasciotti and Wagner, 2015), and the value of crops grown by the household (Muller, 2009; Slavchevska, 2015). These coarse measures have two potential drawbacks: on the one hand, they render it hard to grasp the exact contribution of food self-provisioning to nutrition. On the other, it is difficult to pinpoint whether the effect works through an income channel or immediately through the consumption of self-produced foods. To the best of our knowledge, the study by Shively and Sununtnasuk (2015) is among the few controlling explicitly for the amount of self-produced food. Using a similar approach, the rich HIES/LSMS dataset allows us to calculate the share of consumed calories stemming from the household's own production, thus accounting precisely for the extent of food subsistence. Moreover, we carry the analysis further by testing whether food self-provisioning affects nutrient wealth elasticities.

Second, there is little evidence to date on the effect of shocks on food consumption. Within the small existing literature, studies particularly focus on the impact of food price shocks on nutrition (for ex. Block, 2004; D'Souza and Jolliffe, 2013). There are few studies directly analysing the impact of extreme weather events on nutrition. One exception is the study by Arlappa et al. (2011), which observes a significantly lower vitamin A intake among pre-school children in rural India during severe droughts. Moreover, despite the severe damage caused by the extremely harsh 2001/02 winter in Mongolia, we are not aware of any quantitative study investigating the causal effects of *dzud* exposure on the food consumption of Mongolian households.

Results reveal that food self-provisioning affects both dietary quantity and quality. Herding households consume significantly more calories, carbohydrates, animal fats, animal proteins, vitamin A and iron than do non-herding households, holding income and all other factors constant. When accounting for the self-provisioning of food in greater detail, we find that farming food crops has a significant and positive effect on the consumption of calories, carbohydrates, nutrients from vegetal sources, and iron. This effect is especially strong for small-scale herders. In contrast, the self-provisioning of meat and dairy products has ambivalent effects on household food consumption. Herding households that produce a large share of consumed calories through animal husbandry activities have a higher overall intake of energy, nutrients from animal sources, and vitamin A. At the same time, those households consume fewer nutrients from carbohydrates and vegetal sources, the nutrients for which Mongolian households already have the greatest deficiencies. Moreover, the self-provisioning of food lowers the income elasticities of most nutrients, thus making household food consumption less dependent on short-term fluctuations in income. Exposure to the severe 2001/02 winter does not significantly affect household energy intake for the full sample. Yet, exposure to the shock reduces the consumption of animal fat for both small-scale and large-scale herding households. In addition, small-scale herders dependent on food self-provisioning significantly reduce the intake of almost all macro- and micronutrients when affected by the extreme winter. Finally, for small-scale herding households living in shock-affected areas, the link between food self-production and nutrition becomes weaker for the intake of calories, carbohydrates, animal proteins, and vitamin A compared to herders in less shock-affected areas.

The paper proceeds as follows. Section 2.2 provides an overview of livelihoods in Mongolia. Section 2.3 introduces the household survey data. The estimation strategy is outlined in Section 2.4, followed by a discussion of descriptive and multivariate results in Section 2.5. The final section concludes.

2.2 Livelihoods, wellbeing and nutrition in Mongolia

2.2.1 Different livelihoods

People in Mongolia follow strikingly different livelihoods: on the one hand, a large share of the population (about 30.9 percent) lived from herding activities in 2002 (National Statistical Office of Mongolia, 2003), when the household survey data analysed in this article were collected. The number of households that own at least one animal (but that may have additional sources of income) is even larger, making up about 42.6 percent of the population (National Statistical Office of Mongolia, 2003). The majority of herders are nomadic or semi-nomadic, moving their herds between two and 20 or more times per year. Herders typically own a mix of five species: sheep, goats, horses, cattle, and camel. Sheep provide most of the meat for households' subsistence needs. Cattle primarily provide milk that is used for dairy products as well as meat. Cashmere wool derived from goats is an important source of cash income. Horses and camels are mainly used for tending smaller livestock and for transportation; they are also considered a prestigious form of storing wealth. All animal species are also sold as need arises.

On the other hand, urban households (about 57.4 percent of the population in 2002, National Statistical Office of Mongolia (2003)) mostly earn their income from wage employment and small businesses, buying their food from stores and markets. Since the late 1990s, the capital city of Ulaanbaatar experienced rapid population growth. In 2002, about 34.2 percent of the national population lived in Ulaanbaatar (National Statistical Office of Mongolia, 2003). In urban areas, the public sector is an important employer (employing 19 percent of the national labour force), followed by production (14.3 percent), wholesale and retail trade (12 percent), and services (9.2 percent) (National Statistical Office of Mongolia, 2003).

2.2.2 Extreme Weather Events

One commonly identified factor driving poverty in Mongolia is extremely harsh winters (*dzuds*) that cause mass livestock losses. *Dzuds* are caused by various climatic conditions, often by a combination of several events (Batima, 2006; Murphy, 2011). Among them are too little precipitation; extremely cold temperatures; and fluctuations in winter temperatures above and below zero degree Celsius. *Dzuds* are reinforced by local geographic features, such as the ecological zone, altitude and location on a slope. As meteorological conditions vary unexpectedly in time and space, it is difficult to predict when and where *dzuds* occur.

Between 1999 and 2002, three consecutive *dzud* winters caused excessive livestock death (see Figure A.1 in the Appendix). Climatic conditions during the three *dzud* winters followed a similar pattern: a drought during the summer prevented the animals from building up enough fat reserves for the following winter. Unusually early and heavy snowfall in combination with temperatures that remained well below average levels for a prolonged period of time led to thick ice covering large parts of the country, which prevented animals from reaching the grass. Then severe snowstorms during early spring resulted in more livestock losses. The winters of 1999/00, 2000/01, and 2001/02 caused the death of 10.3, 15.4, and 10.8 percent of livestock, respectively. Yet, in each winter different regions of the country were affected by the *dzud*, with weak correlation of district-level *dzud* intensity across the three *dzud* years. In our analysis, we focus exclusively on the impact of the *dzud* in the winter of

2001/02 on food intake, which occurred immediately before the household survey was implemented.[2]

The socioeconomic consequences of *dzuds* are severe. The public social safety net had virtually collapsed at the beginning of the transition period in the early 1990s and formal insurance markets are not well developed in rural Mongolia. Apart from emergency aid provided on an ad hoc basis, herding households were largely left to their own devices, using informal strategies to cope with the consequences of *dzuds*. Yet, given the severity and covariate nature of *dzuds* within localities, the effectiveness of informal risk management mechanisms is limited; consequently, "high levels of livestock mortality are often unavoidable even for the most experienced herders" (Mahul and Skees, 2007, p. 10). A large number of herders lost a large share of their herd and could no longer sustain a livelihood in the herding economy.

2.3 Data

Our analysis builds on the Household Income and Expenditure Survey/Living Standards Measurements Survey (HIES/LSMS) collected in Mongolia by the NSO, the World Bank, and UNDP in 2002/03. This dataset is an intersection of two separate surveys: the HIES recorded household consumption and income over a period of three consecutive months as well as basic household demographics in 2002. The LSMS revisited a random subsample of surveyed households in 2003 and recorded the socioeconomic status and wealth of those households in great detail. Our analysis builds on a sample of 2788 households that were interviewed in both surveys. All analyses presented in the following were weighted in accordance with the survey design. A detailed description of the data as well as the variables we constructed is provided in the Appendix.

[2]We also test if the *dzud* in the winters of 1999/00 and 2000/01 influenced food consumption, but – in line with our expectations – we do not find systematic patterns (results available upon request).

The data provide a very detailed record of food consumption, which was collected with diaries. Each sample household filled in a consumption diary for three consecutive months. Based on these diaries we calculate the quantity of the different nutrients consumed, scaling it to household composition and adjusting it for the number of guests staying overnight. In addition, we calculate households' expenditures on food and non-food consumption, household income, and the current value of durables. Consumption expenditures and income are expressed in adult equivalents and adjusted for seasonal and locational price differences using a Paasche price index.

2.4 Estimation strategy

The aim of our analysis is to investigate the role of food self-provisioning for nutrient intake. As a first step, we analyse nutrient wealth elasticities across and within different livelihood groups that differ strongly in the extent to which they produce food within the household economy. In a second step, we explore in more detail the impact of the self-provisioning of food on nutrient consumption within livelihood groups. In a third step, we investigate the effect of an extreme weather event on nutrition patterns and the role of food self-provisioning.

Following standard practice in the literature on nutrition, the theoretical starting point for our investigation is household utility (for ex. Behrman et al., 1997; Pitt and Rosenzweig, 1985). We base our analysis on the agricultural household model taking market imperfections – mainly incomplete food markets due to remoteness – into account. Household utility is thus not only a function of the household's consumption but also of its production decision and production factors (Singh et al., 1986).

In a first step, we explore the heterogeneity in nutrition patterns and the nutrient wealth elasticities across different livelihoods. We employ a reduced form equation and estimate the determinants of nutrient consumption for household i in province j in month k as follows:

$$
\begin{aligned}
ln(Nut_{ijk}) = {} & \alpha_0 + \beta_1 small\,scale\,herder_i + \beta_2 large\,scale\,herder_i + \beta_3 ln(income_i) \\
& + \beta_4 X_i + \beta_5 Z_i + \alpha_1 ln(priceindex_{jk}) + \alpha_2 provinceFE_j \\
& + \alpha_3 monthFE_k + \epsilon_{ijk}
\end{aligned}
\tag{2.1}
$$

where *Nut* represents the natural logarithm of daily quantities consumed per adult equivalent of a given nutrient. We employ six macronutrients as outcomes (calories, carbohydrates, animal proteins, vegetable proteins, animal fats, and vegetable fats) and two micronutrients (iron and vitamin A).

We first estimate Equation 2.1 for the full sample of households, including two indicator variables for small-scale and large-scale herding households. We define as small-scale herders those households that own between 1 and 99 animals and, thus, self-provision at least some of their consumption needs (48 percent of sample households). Large-scale herders are defined as those with a herd size of 100 animals or more (16 percent of sample households). In Mongolia, this threshold is commonly considered the minimal herd size to derive a livelihood from herding (Goodland et al., 2009). We then estimate the model separately for small-scale herders, large-scale herders, and non-herding households. This way, we analyse the link between agriculture and nutrition within relatively homogenous groups of households that share similarities in market access and market characteristics (see Table A.1 in the Appendix). In fact, there is a strong correlation between livelihood group, location, and access to (food) markets: about 94 percent of non-herding households live in Ulaanbaatar or provincial capitals (where multiple grocery stores and food markets exist) while 67 percent of large-scale herders living in the countryside (where most households live in scattered campsites and hence no markets exist). The category of small-scale herders is in-between, with about 50 percent of small-scale herders residing in provincial capitals or district centres (which have at least one grocery shop offering a basic supply of goods) and 33 percent living in the countryside.

Income stands for the daily income per adult equivalent. As both income and outcomes are logarithmically transformed, the coefficient can be interpreted as elasticity. We prefer income over consumption expenditures to measure household wealth for two reasons: first, most rural households produce and consume their own meat and dairy products. Markets and, hence, prices for the most important food products do not exist in rural areas. Thus, assigning realistic values for food produced and consumed within pastoralist households is challenging. Moreover, the population density in Mongolia is extremely low, with about 1.58 people per square kilometre in 2002 (National Statistical Office of Mongolia, 2003). This makes it even more difficult to derive a monetary value for food produced by pastoralists, who often have their campsites far from the nearest market. Second, there is a specific disadvantage of using food consumption expenditures as wealth measure: the outcome variable and the wealth measure would be derived from the same original survey question, which may create correlated errors and upward-biased results (for ex. Bouis and Haddad, 1992). As a robustness test, we employ alternative wealth measures – consumption expenditures for food and non-food items, as well as the value of durables – and obtain similar results, as will be discussed below.

The estimation of the determinants of nutrition demand is challenged by an endogeneity problem, which is widely discussed in the literature on the subject (Bouis and Haddad, 1992). Not only can household wealth influence nutrient intake but nutrition can impact household income, particularly through the wages a person can earn if he or she is in better physical condition due to better nutrition (Strauss and Thomas, 1998). In addition to this potential reverse causality, the estimated effect of wealth could be biased by an omitted variable that affects both wealth and nutrition. We address this issue by employing an instrumental variable approach as a robustness test. Following Skoufias et al. (2009), household income is instrumented by the median income in the enumeration area and household total consumption expenditures are instrumented by the median non-food expenditures in the enumeration area. To be valid, each instrument should be correlated with the respective wealth measure (which they are), while the instruments should not be correlated with unobserved household characteristics explaining nutrient consumption (which we consider to be likely in our context).

We also control for production factors (vector X). This way, we account for the fact that in the presence of market imperfections, household consumption and production decisions are no longer separable (Singh et al., 1986). Most importantly, for herding households we control for the number of livestock each household owns. While the number of livestock holdings is subject to the household's decision-making, we argue that, for two reasons, livestock holdings can be considered fixed in the medium term, thus being independent of the household's food consumption decisions. First, during the socialist era, most livestock activities were organised in collective production units characterised by a very high division of labour, while households were only permitted to own a limited number of private livestock. With the beginning of the transition period in the early 1990s, cooperatives were privatised based on a voucher system with individuals given asset shares and livestock from the former cooperatives (Bedunah and Schmidt, 2004). Thus, households were allocated most of their initial animal stock only 10 years before the survey period. Second, consecutive winter disasters between 1999 and 2001 – immediately prior to our period of investigation – resulted in mass livestock losses, further exogenously decimating herd sizes.

Another production factor is the distance to the nearest water source, which is relevant for both herding and farming activities given the dry climatic conditions in Mongolia. We also control for vehicle ownership and the distance to the nearest health centre.[3] The latter measures remoteness, indicating both the household's non-herding income generating opportunities and the degree of household-specific market failures. For several reasons, herders' location – and hence the distance variables – can be considered exogenous (at least in the medium term). While land is state property, there are complex systems of customary rights over campsites. For instance, by investing in shel-

[3]Both the distance to the nearest water source and the nearest health centre are logarithmically transformed. To avoid losing households that live next to a water source or health centre, we follow the approach discussed by Battese (1997). Our regressions include two variables for each distance measure: D and $log(distance + D)$, where D is a dummy variable that takes the value of one if the household reports a distance of less than two km and zero otherwise.

ters, building up animal dung, as well as constructing and maintaining wells, herders underline their use rights over campsites. Use rights over campsites are also passed on from generation to generation. In addition, despite the extremely low population density in rural Mongolia, grazing lands surrounding settlements have been over-exploited (Goodland et al., 2009).

The vector Z represents household-level controls.[4] These include household size, the share of children under the age of six years in the household, whether the head of household is female, age of the head, and education of the most senior woman in the household (in years). The latter reflects the predominant role mothers play in the nutrition of household members and, in particular, children (Block, 2004).

Province fixed effects account for the fact that both demand and supply factors for food may differ across provinces. These include, for instance, the supply of regionally grown food products, regional consumption habits, the potential for agricultural activities and the proximity to the capital city Ulaanbaatar, which influences both the prices and the availability of imported foods. Month fixed effects control for seasonal differences in food prices, which fluctuate considerably across the year. Also, daily calorie requirements are much higher during the extremely cold winter months, particularly for herders working outdoors. A price index accounts for the province-level time trends in prices. Lastly, ϵ_{ijk} is a random idiosyncratic error term clustered at the enumeration area level. Summary statistics of all variables used are displayed in Table 2.1.

In a second step, we account in more detail for the extent of self-provisioning of food and analyse its impact on nutrient intake with the following model:

[4]We also use discriminant analysis in order to identify further control variables, given that few of the theoretically predicted covariates are statistically significant. Results from discriminant analysis pointed toward the importance of time and regional effects for making households "low consumers".

Table 2.1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Dependent variables (quantity consumed per day per adult equivalent)					
Calories	2,189	983.68	500.93	5,994	2,788
Carbohydrates (g)	315.68	137.29	26.16	1,045	2,788
Animal proteins (g)	46.02	42.58	0	422.9	2,788
Vegetal proteins (g)	42.62	18.97	0	146.77	2,788
Animal fat (g)	44.88	38.95	0	302.96	2,788
Vegetal fat (g)	16.64	13.6	0	136.03	2,788
Iron (mg)	19.14	10.75	2.47	129.01	2,788
Vitamin A (mg)	1.25	1.75	0	37.79	2,788
Livelihood groups					
Small-scale herding household (1–99 livestock)	0.45	0.5	0	1	2,788
Large-scale herding household (100 and more livestock)	0.19	0.39	0	1	2,788
Non-herding household	0.36	0.48	0	1	2,788
Wealth					
Income per adult equivalent per month (in 1,000 MNT)	26.31	30.2	1.02	671.33	2,788
Consumption expend. per adult equivalent per month (in 1,000 MNT)	27.46	21.12	4.75	162.41	2,788
Value of durables per adult equivalent (in 1,000 MNT)	1,278	2,122	10.29	27,619	2,788
Food self-provisioning					
Share of calories from own animal husbandry	0.15	0.19	0	0.88	2,788
Consumed crops from own farming	0.17	0.37	0	1	2,788
Production and market access					
Distance to nearest water source (in km)	0.85	1.96	0	30	2,788
Number of livestock[a]	58.87	98.46	0	1,747	2,788
Distance to nearest health centre (in km)	6.19	12.07	0	140	2,788
Vehicle ownership	0.31	0.46	0	1	2,788
Socio-demographic characteristics					
Household size	5.25	1.92	1	15	2,788
Share of children below age 6	0.1	0.14	0	0.67	2,788
Female household head	0.13	0.33	0	1	2,788
Education of most senior woman (in years)	9.86	3.26	1	23	2,788
Age of household head	44.53	12.56	15	92	2,788
Ulaanbaatar or provincial capital	0.56	0.5	0	1	2,788
District centre	0.16	0.37	0	1	2,788
Rural	0.28	0.45	0	1	2,788
Prices					
Price index (monthly, at province level)	172.71	45.07	107.5	242.3	2,788
Shock measure					
Standardized sheep mortality per district in 2002	0.33	0.85	−0.37	3.59	1,720

In 2002, 1000 Mongolian Tugrik (MNT) were worth 0.89 USD. [a]In the multivariate analyses below, this variable is expressed in adult equivalent terms. For each household, two months of data from consumption diaries are used. Observations from February, April, July and October are excluded. Source: HIES/LSMS 2002/03.

$$
\begin{aligned}
ln(Nut_{ijk}) = \alpha_0 &+ \beta_1 food\,selfprovisioning_i + \beta_2 ln(income_i) \\
&+ \beta_3 food\,selfprovisioning_i * ln(income_i) + \beta_4 X_i + \beta_5 Z_i \\
&+ \alpha_1 ln(priceindex_{jk}) + \alpha_2 provinceFE_j + \alpha_3 monthFE_k + \epsilon_{ijk}
\end{aligned} \tag{2.2}
$$

The $food\,self-provisioning$ vector comprises two variables. First, for herding households, we employ the share of consumed calories from meat and dairy products that a household self-provisions through animal husbandry out of the total amount of calories consumed by the household. Second, for both herding and non-herding households, we include an indicator variable taking the value one if a household consumed any fruits, vegetables, or other self-produced crops. In remote areas, the supply of fresh fruits and vegetables is limited. Thus, although farming activities are mostly small scale, often consisting of backyard gardening, this may still be one way to reduce the prevalent deficiencies in vitamins and enrich the dietary diversity of households. Besides exploring the level effects of food self-provisioning, we also interact these variables with income. This allows us to explore whether the self-provisioning of food affects the nutrient wealth elasticities.

One concern that arises in this reduced form model is that there may be unobserved factors at play that influence both the extent to which households are autarkic in their food production and the error term. We acknowledge that concerns of endogeneity (and also reversed causality) could only be fully ruled out with panel data, an instrumental variable approach, or some agricultural intervention implemented with randomisation, none of which is available in this context.[5] Yet, we hope to minimise concerns of endogeneity by two factors. First, we purposefully define the extent of food self-provisioning in relative terms, as share of total calories consumed. This approach reduces the bias stemming from differences in absolute levels of nutrient intake across households. Second, we estimate the model separately for small-scale herders, large-scale herders, and non-herding households, as-

[5] We experimented with remoteness as instrument for the share of food self-production. However, none of the specifications fulfilled the requirements for strong instruments, so results are not reported here.

sessing the effect of food self-provisioning within each livelihood group. By definition, the self-provisioning of food differs strongly across the three livelihood groups and reflects varying market access. Moreover, by estimating the model separately for each livelihood group, we avoid modelling the decision to follow a herding livelihood – and thus self-provision meat and dairy products at all.

In a third step, we test whether exposure to the extremely harsh winter of 2001/02 influenced nutrition intake and the self-provisioning of food among herding households. The HIES/LSMS survey questionnaire does not record household-level information on exposure to the shock. Thus, we must resort to district-level data to construct a measure of shock intensity. We use historic livestock census data collected by the NSO, which are available for each year from 1970 onward at the district level (with 69 districts covered by the HIES/LSMS). For each district, we subtract from the sheep mortality in 2002 the mean sheep mortality over the 1970–2001 period in the same district and divide the term by the standard deviation of local sheep mortality.[6] By relating sheep mortality occurring during the *dzud* winter to the long-term local patterns in sheep mortality, we account for the experience that households gathered over time in coping with the risk of extreme weather events. The intensity index varies between -0.37 (indicating lower or "better" than average livestock mortality) and 3.59 (the most severely affected district) across survey districts. As mutton is by far the most widely consumed meat, sheep losses should capture the potential nutrition effect of the *dzud* most directly.

The shock measure is included as additional vector in Equation (2), with all other variables included as discussed above. The estimated coefficient of the shock measure can be interpreted as causal effect under the assumption that households did not anticipate the magnitude of livestock losses caused by the *dzud*. Two empirical observations speak in favour of this assumption: first, the severity of the 2001/02 *dzud* was extreme. Sheep mortality in 2002 was as high as 72 percent in some survey districts. Second, the occurrence of

[6]See Groppo and Kraehnert (2016) for details on the construction of the index and the data source.

dzuds in three consecutive winters (although not occurring in the same localities) is extremely unusual.

In addition, the shock measure is interacted with the two food self-provisioning variables. This way, we explore whether *dzud* exposure changes the role food self-provisioning plays for nutrient intake. However, we caution that the estimated coefficient should only be interpreted as correlation rather than causality given that households might change the amount of food self-provisioning in response to the shock but also as pre-emptive measure.

2.5 Results

2.5.1 Nutrition patterns across livelihood groups

Table 2.2 provides unconditional statistics on the availability and adequacy ratios of various nutrients across livelihood groups. The overall energy intake for small-scale and large-scale herders is 2266 and 2576 calories per day per adult equivalent, respectively. This corresponds closely to the recommended energy intake in Mongolia. In contrast, the calorie consumption of non-herding households is much lower, which in part reflects a lower level of physical labour: these households consume an average of 2004 calories per day per adult equivalent, which corresponds to an adequacy ratio of only 80 percent.[7] Table 2.2 also shows that adequacy ratios diverge even more across livelihood groups for nutrients stemming from animal sources. Herding households with small and large herds consume about 95 percent and 139 percent of the recommended quantity of animal proteins, respectively. Both types of herding households consume more than twice the recommended amount of animal fats. In contrast, for non-herding households, the adequacy ratio in animal proteins is only 46 percent, an alarmingly low level. This pattern is inversed for vegetal fat intake, which is much higher for non-herding households (but still only half of the recommended level). Vegetal fat is the nutrient that shows the greatest deficiencies for herders, with adequacy ratios

[7] The role of food consumed outside the homestead for overall energy intake is discussed in footnote 3 of Appendix A.

of only 28–36 percent.

Table 2.2: Availability and adequacy of nutrient intake (per adult equivalent per day)

	Small-scale herding households (N=1,322)		Large-scale herding households (N=449)		Non-herding households (N=1,007)	
	Availability	Adequacy ratio	Availability	Adequacy ratio	Availability	Adequacy ratio
Calories	2,266	0.91	2,576	1.03	2,004	0.80
Carbohydrates (g)	316.88	0.85	328.69	0.88	312.29	0.83
Animal proteins (g)	53.32	0.95	77.70	1.39	25.77	0.46
Vegetal proteins (g)	42.28	1.11	43.21	1.14	42.89	1.13
Animal fat (g)	51.27	1.83	71.56	2.56	29.36	1.05
Vegetal fat (g)	15.09	0.36	11.63	0.28	21.93	0.52

Recommendations for nutrient intakes are taken from Amartuvshin (2011). For each household, two months of data from consumption diaries are used. Observations from February, April, July and October are excluded. Source: HIES/LSMS 2002/03.

Next, we estimate the nutrition provision function (Equation 2.1) for eight different nutrients in a multivariate regression (Table 2.3). Results show that both types of herding households consume significantly more calories, carbohydrates, nutrients from animal sources, iron, and vitamin A per day per adult equivalent than non-herding households, holding all other factors constant. The estimated effects are also economically large. For instance, herders with small and large herds consume about 10 percent and 20.6 percent more calories and 9.5 percent and 18.6 percent more iron, respectively, than do non-herding households. The estimated coefficients are statistically significant at the 1 percent level. Although the energy needs of herders are higher due to their strenuous work outside, these households are also able to consume more of most of the other nutrients studied than basic needs call for, thus making their overall nutritional situation appear better than that of non-herding households.

As a next step, we explore the nutrient income elasticities *across* livelihoods (Table 2.4). Results are now presented separately for small-scale herders (Panel A), large-scale herders (Panel B), and non-herding households (Panel C). All of the estimated nutrient income elasticities are positive and highly statistically significant. Two findings are noteworthy: first, income has a sur-

Table 2.3: Determinants of nutrient intake

Dependent Variable	Calories	Carbo-hydrates	Animal proteins	Vegetal proteins	Animal fat	Vegetal fat	Iron	Vitamin A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Small-scale herder	0.100***	0.042**	0.338***	0.023	0.321***	-0.015	0.095***	0.304***
	(0.018)	(0.019)	(0.035)	(0.020)	(0.038)	(0.036)	(0.024)	(0.043)
Large-scale herder	0.206***	0.095***	0.605***	0.047	0.587***	-0.035	0.186***	0.531***
	(0.030)	(0.031)	(0.053)	(0.031)	(0.058)	(0.059)	(0.035)	(0.059)
Income	0.156***	0.136***	0.189***	0.110***	0.223***	0.293***	0.120***	0.220***
	(0.010)	(0.011)	(0.016)	(0.011)	(0.017)	(0.017)	(0.011)	(0.020)
Household lives at a water source	-0.004	-0.001	0.022	-0.014	-0.008	-0.009	-0.008	0.106*
	(0.024)	(0.026)	(0.037)	(0.030)	(0.044)	(0.041)	(0.026)	(0.054)
Distance to nearest water source	0.012	-0.007	0.060*	-0.009	0.029	0.019	0.024	0.046
	(0.020)	(0.022)	(0.032)	(0.025)	(0.035)	V0.037)	(0.024)	(0.039)
Vehicle ownership	0.023	0.023	0.014	0.018	0.025	0.034	0.002	0.027
	(0.015)	(0.017)	(0.026)	(0.018)	(0.027)	(0.029)	(0.019)	(0.030)
Household lives at a health centre	-0.004	-0.006	-0.018	-0.004	-0.008	0.019	-0.04	0.068
	(0.027)	(0.029)	(0.048)	(0.034)	(0.049)	(0.053)	(0.032)	(0.076)
Distance to nearest health centre	0.015	0.001	0.048*	-0.006	0.058**	-0.023	-0.004	0.100***
	(0.014)	(0.015)	(0.029)	(0.018)	(0.029)	(0.028)	(0.017)	(0.033)
Household size	-0.062***	-0.053***	-0.088***	-0.052***	-0.080***	-0.052***	-0.067***	-0.090***
	(0.004)	(0.004)	(0.007)	(0.005)	(0.008)	(0.008)	(0.006)	(0.009)
Share of children	0.219***	0.192***	0.373***	0.147**	0.316***	0.076	0.288***	0.449***
	(0.056)	V0.059)	(0.085)	(0.063)	(0.090)	(0.110)	(0.064)	(0.108)
Female head	-0.027	-0.024	-0.039	-0.023	-0.019	-0.017	-0.013	-0.047
	(0.020)	(0.022)	(0.032)	(0.023)	(0.038)	(0.043)	(0.026)	(0.040)
Education of most senior woman	0.002	0.000	0.012***	-0.001	0.007	0.014***	-0.006*	0.014***
	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)	(0.005)	(0.003)	(0.005)
Age of head	0.000	-0.001	0.003***	-0.001	0.002**	-0.002*	0.000	0.004**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
District centre	-0.006	-0.058*	0.212***	-0.066**	0.151***	-0.258***	0.007	0.039
	(0.028)	(0.030)	(0.048)	(0.032)	(0.054)	(0.059)	(0.033)	(0.059)
Rural	0.092**	-0.006	0.464***	-0.036	0.392***	-0.395***	0.090**	0.354***
	(0.036)	(0.035)	(0.074)	(0.038)	(0.078)	(0.075)	(0.040)	(0.081)
CPI	-1.245**	-1.042*	-0.406	-0.679	-1.634	-1.553	-1.479**	-3.546***
	(0.588)	(0.556)	(1.171)	(0.594)	(1.090)	(0.981)	(0.687)	(1.264)
Month FE	yes	yes	yes	yes	yes	yes	yes	yes
Province FE	yes	yes	yes	yes	yes	yes	yes	yes
Number of households	2,788	2,788	2,783	2,787	2,784	2,786	2,788	2,786
R2	0.323	0.204	0.461	0.156	0.37	0.366	0.339	0.283

Notes: The dependent variables, income, the distance to the nearest water source and health centre, and the price index are logarithmically transformed. For each distance measure, two variables are included: D and $log(distance + D)$, where D – here named "Household lives at a health centre/ water source" – is a dummy variable that takes the value of one if the household reports a distance of less than two km and zero otherwise. Displayed are coefficients estimated with OLS with *** p<0.01, ** p<0.05, * p<0.1 and standard errors in parentheses. For each household, two months of data from consumption diaries are used. Observations from February, April, July and October are excluded. Source: HIES/LSMS 2002/03.

prisingly homogeneous effect on nutrient intake across different livelihood groups. For instance, the income elasticities of calorie intake range from 0.15 for herders to 0.18 for non-herders, with the difference between them not statistically significant. Thus, it appears that short-term fluctuations in household income have a very similar effect on food consumption among herding households that derive a share of the consumption needs through own herding activities and among non-herding households that buy almost all food in the market.

Second, vegetal fat, animal fat, and vitamin A intake have the highest income elasticities (irrespective of the livelihood group), similar to the findings of Skoufias et al. (2009) in Mexico. Thus, the consumption of vegetal fat, animal fat, and vitamin A responds more strongly than other nutrients to short-term income fluctuations. This indicates that households may substitute food items in times of stress to keep overall energy intake constant. Such substitution could occur both within food groups – for example, by replacing meat with less expensive (and less rich in fat) animal interior – and across food groups. A number of non-meat food items (such as beans) provide the same amount of energy at lower prices.

Table 2.4: Nutrient wealth elasticities

Dependent Variable	Calories	Carbohydrates	Animal proteins	Vegetal proteins	Animal fat	Vegetal fat	Iron	Vitamin A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Small-scale herding households								
Income	0.146***	0.132***	0.161***	0.105***	0.201***	0.285***	0.113***	0.188***
	(0.012)	(0.014)	(0.023)	(0.015)	(0.025)	(0.025)	(0.015)	(0.025)
Consumption expenditures	0.377***	0.291***	0.570***	0.230***	0.604***	0.506***	0.280***	0.668***
	(0.016)	(0.019)	(0.028)	(0.021)	(0.033)	(0.035)	(0.022)	(0.041)
Durables	0.032**	0.017	0.078***	0.003	0.090***	0.049*	0.004	0.085***
	(0.013)	(0.014)	(0.023)	(0.014)	(0.025)	(0.028)	(0.014)	(0.029)
Instrumented income	0.140***	0.112***	0.211***	0.083***	0.250***	0.311***	0.143***	0.224***
	(0.026)	(0.027)	(0.054)	(0.029)	(0.055)	(0.056)	(0.035)	(0.057)
Instrumented cons. expenditures	0.192***	0.125**	0.313***	0.095*	0.360***	0.588***	0.194***	0.299***
	(0.046)	(0.050)	(0.080)	(0.055)	(0.088)	(0.098)	(0.063)	(0.102)
F-test instrumented income	924.77	924.77	914.23	925.32	914.23	925.43	924.77	914.11
Adj. Partial R2 instrumented inc.	0.250	0.250	0.250	0.250	0.248	0.250	0.250	0.250
F-test instrumented cons. expend.	228.32	228.32	230.48	228.64	230.48	228.64	228.32	231.85
Adj. Partial R2 instr. cons expend.	0.139	0.139	0.140	0.139	0.140	0.139	0.139	0.140
Number of households	1,332	1,332	1,329	1,332	1,329	1,331	1,332	1,332

Continued on next page...

... table 2.4 continued

Dependent Variable	Calories	Carbohydrates	Animal proteins	Vegetal proteins	Animal fat	Vegetal fat	Iron	Vitamin A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel B: Large-scale herding households								
Income	0.145***	0.130***	0.128***	0.113***	0.163***	0.296***	0.123***	0.119***
	(0.018)	(0.021)	(0.029)	(0.022)	(0.026)	(0.032)	(0.021)	(0.029)
Consumption expenditures	0.425***	0.335***	0.562***	0.315***	0.585***	0.612***	0.387***	0.599***
	(0.032)	(0.035)	(0.050)	(0.040)	(0.053)	(0.059)	(0.034)	(0.050)
Durables	0.033*	0.021	0.037	0.011	0.064*	0.070*	0.002	0.064*
	(0.020)	(0.020)	(0.030)	(0.023)	(0.036)	(0.038)	(0.027)	(0.033)
Instrumented income	0.161***	0.136***	0.156***	0.131***	0.235***	0.232***	0.200***	0.117**
	(0.038)	(0.042)	(0.059)	(0.043)	(0.052)	(0.061)	(0.044)	(0.053)
Instrumented cons. expenditures	0.254***	0.15	0.249**	0.158	0.501***	0.508***	0.283***	0.343***
	(0.079)	(0.096)	(0.121)	(0.104)	(0.128)	(0.130)	(0.093)	(0.118)
F-test instrumented income	304.86	304.86	304.75	304.86	304.75	304.86	304.86	304.86
Adj. Partial R2 instrumented inc.	0.252	0.252	0.252	0.252	0.252	0.252	0.252	0.252
F-test instrumented cons. expend.	63.67	63.67	63.57	63.67	63.57	63.67	63.67	63.67
Adj. Partial R2 instr. cons expend.	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
Number of households	449	449	448	449	448	449	449	449

Continued on next page...

... table 2.4 continued

Dependent Variable	Calories	Carbohydrates	Animal proteins	Vegetal proteins	Animal fat	Vegetal fat	Iron	Vitamin A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel C: Non-herding households								
Income	0.175***	0.143***	0.269***	0.116***	0.284***	0.304***	0.125***	0.357***
	(0.015)	(0.018)	(0.023)	(0.019)	(0.027)	(0.027)	(0.019)	(0.044)
Consumption expenditures	0.361***	0.317***	0.481***	0.275***	0.518***	0.538***	0.328***	0.591***
	(0.016)	(0.018)	(0.023)	(0.018)	(0.029)	(0.032)	(0.021)	(0.040)
Durables	0.018	0.003	0.081***	-0.001	0.070***	0.043**	-0.015	0.098***
	(0.012)	(0.012)	(0.017)	(0.013)	(0.019)	(0.020)	(0.016)	(0.022)
Instrumented income	0.224***	0.180***	0.369***	0.141***	0.368***	0.468***	0.163***	0.476***
	(0.035)	(0.038)	(0.052)	(0.041)	(0.061)	(0.066)	(0.045)	(0.084)
Instrumented cons. expenditures	0.318***	0.248***	0.546***	0.186***	0.483***	0.723***	0.308***	0.644***
	(0.046)	(0.054)	(0.078)	(0.057)	(0.086)	(0.095)	(0.068)	(0.097)
F-test instrumented income	352.78	352.78	351.12	352.75	352.30	352.75	352.78	352.57
Adj. Partial R2 instrumented inc.	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.170
F-test instrumented cons. expend.	204.38	204.38	203.87	204.21	203.9	204.21	204.38	215.68
Adj. Partial R2 instr. cons expend.	0.108	0.108	0.108	0.109	0.108	0.109	0.108	0.11
Number of households	1,007	1,007	1,006	1,006	1,006	1,006	1,007	1,006

Notes: All dependent variables and all wealth measures are logarithmically transformed. All regressions include the complete set of controls as in Table 2.3. Income is instrumented by the median income in the enumeration area. Consumption expenditures are instrumented by the median non-food expenditures in the enumeration area. Displayed are coefficients estimated with OLS and IV with *** $p<0.01$, ** $p<0.05$, * $p<0.1$ and standard errors in parentheses. For each household, two months of data from consumption diaries are used. Observations from February, April, July and October are excluded. Source: HIES/LSMS 2002/03.

As a robustness test, we estimate the nutrition provision function (Equation 2.1) separately for two alternative wealth measures, consumption expenditures and durables (Table 2.4). Results are in line with our findings for the nutrient-income elasticities: all of the estimated nutrient wealth elasticities are positive and almost all are statistically significant. When comparing the various nutrient wealth elasticities, we find that the consumption expenditure elasticities are much higher than the income elasticities for nutrient intake. This result holds for all three types of households studied and for all eight nutrients. This could suggest that households are relatively well equipped to cushion short-term income fluctuations (measured with income), while their nutrient intake responds more strongly to changes in permanent income (measured with consumption expenditures). Furthermore, OLS and IV approaches yield very similar results for the nutrient elasticity of income and consumption expenditures, both in terms of the level of significance and the magnitude of the estimated elasticity. This holds for all nutrients and for all three groups of households. Therefore, we are confident that our results are not driven by endogeneity and omitted variable problems.

2.5.2 Accounting for the amount of food self-provisioning

Descriptive statistics show large differences between the three groups of households in terms of the extent of self-production of food (Table A.1 in the Appendix). About 23 percent of small-scale and 26 percent of large-scale herders cultivate food crops, compared to only 5 percent of non-herding households. Small-scale and large-scale herders provision between 20 and 35 percent of the calories consumed within the household through animal husbandry, respectively. Large-scale herders are close to self-sufficient in meat and dairy products (producing 86 percent and 72 percent of the consumed calories of meat and dairy products, respectively), while small-scale herders produce about half of the consumed meat and dairy products within the household economy.[8] In turn, the quantity of meat consumed varies across livelihood groups: non-herding households, small-scale herders and large-scale herders derive on average 14 percent, 23 percent and 29 percent, respectively, of their

[8] The category "meat" includes sausages and canned meat, which are always bought in stores.

calories from meat.

Next, we exploit differences in the extent of food self-provisioning within livelihood groups and investigate its impact on the intake of nutrients, using a multivariate regression (Table 2.5). Results indicate that food self-provisioning has a significant impact on the amount of different nutrients consumed. This effect is most pronounced for small-scale herding households (Panel A) that derive their sustenance from multiple sources. For those households, consuming crops from own farming has a statistically significant and positive effect on the intake of calories, carbohydrates, and nutrients from vegetal sources. For instance, small-scale herding households that do farming activities consume an average of 6 percent more calories per day per adult equivalent than small-scale herding households that do not farm. The magnitude of the effect of food self-provisioning through farming is particularly large for vegetal fats – for which small-scale herding households exhibit the largest deficiencies.

In contrast, the provision of meat and dairy products through the household's animal husbandry activities has ambivalent effects on the household's diet. On the one hand, the *share of calories from own animal husbandry* is significantly and positively related to the intake of calories.[9] For instance, for large-scale herders with average income, increasing the share of calories from own production by one percentage point is associated with a 0.39 percent higher calorie intake (Table 2.5, Panel B). The intake of vitamin A and nutrients from animal sources responds disproportionately to an increase in the share of self-provisioned food. For both types of herding households with average income, a one percentage point increase in the share of calories from own production is associated with a 2.5 percent increase in the intake of animal proteins. On the other hand, the share of food consumed from own meat and dairy production significantly decreases the intake of carbohydrates and nutrients from vegetal sources. The effect is economically large: for small-scale herders with mean income, increasing the share of self-provisioned calories from own an-

[9]As robustness test, we also estimate Equation 2.2 with the share of calories consumed from own meat and dairy production transformed into a binary variable. All results described here still hold, irrespective of whether the cut-off is set at 25 percent, 30 percent or 35 percent of calorie consumption from own production.

Table 2.5: The effect of food self-provisioning

Dependent Variable	Calories	Carbo-hydrates	Animal proteins	Vegetal proteins	Animal fat	Vegetal fat	Iron	Vitamin A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Small-scale herding households								
Income	0.157***	0.142***	0.167***	0.116***	0.208***	0.295***	0.123***	0.185***
	(0.013)	(0.014)	(0.021)	(0.015)	(0.024)	(0.029)	(0.017)	(0.027)
Share of calories from own animal husbandry	0.363***	-0.551***	2.518***	-0.879***	2.705***	-1.435***	-0.037	2.485***
	(0.080)	(0.088)	(0.125)	(0.087)	(0.119)	(0.158)	(0.090)	(0.151)
Consumed crops from own farming	0.056**	0.075***	0.004	0.070***	-0.017	0.127**	0.040	0.02
	(0.023)	(0.025)	(0.032)	(0.026)	(0.037)	(0.050)	(0.025)	(0.036)
Income*Share of calories	-0.061	-0.010	-0.212**	0.034	-0.299***	0.114	0.087	-0.444***
	(0.063)	(0.068)	(0.102)	(0.069)	(0.105)	(0.111)	(0.077)	(0.126)
Income*Consumed crops	-0.040	-0.029	-0.032	-0.032	-0.034	-0.025	-0.041	0.015
	(0.026)	(0.027)	(0.034)	(0.026)	(0.040)	(0.053)	(0.026)	(0.040)
Number of households	1,332	1,332	1,329	1,332	1,329	1,331	1,332	1,332
R-squared	0.361	0.267	0.555	0.245	0.537	0.412	0.337	0.414
Panel B: Large-scale herding households								
Income	0.147***	0.125***	0.136***	0.104***	0.181***	0.311***	0.126***	0.123***
	(0.019)	(0.021)	(0.027)	(0.022)	(0.020)	(0.031)	(0.022)	(0.031)
Share of calories from own animal husbandry	0.385***	-0.803***	2.502***	-1.089***	2.935***	-1.713***	0.120	2.386***
	(0.115)	(0.118)	(0.176)	(0.150)	(0.179)	(0.233)	(0.155)	(0.196)
Consumed crops from own farming	0.030	0.037	0.032	0.048	0.024	0.123	0.048	0.024
	(0.037)	(0.040)	(0.044)	(0.040)	(0.047)	(0.075)	(0.046)	(0.044)
Income*Share of calories	-0.006	0.068	-0.037	0.088	-0.124	0.057	0.083	-0.016
	(0.092)	(0.112)	(0.131)	(0.111)	(0.134)	(0.151)	(0.091)	(0.164)
Income*Consumed crops	0.001	0.007	0.006	0.014	-0.017	-0.076	-0.011	0.021
	(0.030)	(0.033)	(0.042)	(0.033)	(0.034)	(0.050)	(0.038)	(0.043)
Number of households	449	449	448	449	448	449	449	449
R-squared	0.459	0.385	0.59	0.354	0.646	0.466	0.452	0.541
Panel C: Non-herding households								
Income	0.181***	0.149***	0.273***	0.124***	0.286***	0.313***	0.132***	0.368***
	(0.016)	(0.018)	(0.024)	(0.019)	(0.028)	(0.028)	(0.020)	(0.046)
Consumed crops from own farming	0.061	0.090**	0.051	0.084*	0.051	0.049	0.138***	-0.014
	(0.044)	(0.046)	(0.060)	(0.048)	(0.067)	(0.076)	(0.043)	(0.151)
Income*Consumed crops	-0.119**	-0.121***	-0.07	-0.137***	-0.053	-0.164**	-0.137***	-0.209**
	(0.047)	(0.046)	(0.068)	(0.049)	(0.081)	(0.073)	(0.047)	(0.096)
Number of households	1,007	1,007	1,006	1,007	1,007	1,007	1,007	1,007
R-squared	0.243	0.185	0.279	0.156	0.200	0.210	0.198	0.194

Notes: All dependent variables and income are logarithmically transformed. Income and share of calories from own animal husbandry have been centred to allow for an easier interpretation of the interaction terms. All regressions include the complete set of controls as in Table 2.3. Displayed are coefficients estimated with OLS with *** p<0.01, ** p<0.05, * p<0.1 and standard errors in parentheses. For each household, two months of data from consumption diaries are used. Observations from February, April, July and October are excluded. Source: HIES/LSMS 2002/03.

imal husbandry by one percentage point reduces the intake of vegetal fat by 1.43 percent. Farming only partly counteracts this effect. Thus, food self-provisioning seems to entail substitution effects that change the composition of the household's diet. In particular, a higher share of calories from own animal husbandry is associated with a higher specialisation in the consumption of meat and in turn with a worsened nutritional situation for nutrients from vegetal sources for which households already exhibit the greatest deficiencies.

Interestingly, the self-provisioning of food also influences some of the nutrient income elasticities. For instance, for small-scale herding households (Table 2.5, Panel A), the interaction term between *income* and the *share of calories from own animal husbandry* is statistically significant and negative for animal proteins, animal fat, and vitamin A. Thus, for small-scale herders producing a relatively large share of calories within the household, the intake of those nutrients is less dependent on shortterm fluctuations in income compared to small-scale herders that buy most of their food in the market. We obtain similar results for the income elasticities of calories, carbohydrates, nutrients from vegetal sources, iron, and vitamin A for non-herding households that farm (Panel C). For all of those nutrients, consuming crops from own farming reduces the income elasticity of nutrient intake. In contrast, for herding households with large herds, the self-provisioning of food does not influence the nutrient wealth elasticities. Thus, it seems that the self-provisioning of food stabilizes consumption patterns for small-scale herders and non-herding households, both of which produce only minor shares of their food within the household.

Following de Janvry et al. (1991); Villa et al. (2010), our results might also be interpreted as an empirical test of market failures in local meat markets. As Villa et al. (2010) point out, "increases in household production of those goods [for which market failures exist] would increase consumption of just those goods, but have little to no impact on other household consumption goods" (p. 345). In fact, in the context of Mongolian herders, we not only observe the absence of positive effects of meat self-production on other food groups, but even a negative effect on the intake of other food groups. One possible explanation is that herding households that are highly self-sufficient in meat reside in remote rural areas that render transportation costs to the next district centre costly. Thus, there may be household-specific market failures for other food items, including perishable vegetables. To further explore this channel, we interact remoteness – measured by the distance to the next health centre – with the food self-provisioning variables (results available upon request). Interestingly, the negative effect of the share of calories consumed from own meat and dairy production on the intake of carbohydrates and nutrients from vegetal sources is no longer significant for large-scale herders that reside in the proximity of a health centre and, thus, have good market access. Thus, household-specific market failures seem to exist for households living in remote areas. The self-provisioning of food could be, to some extent, a substitute for market access.

2.5.3 Impact of the 2001/2002 *dzud* on nutrition

Last, we test whether the extremely severe winter of 2001/02 influenced food consumption and the self-provisioning of food among herding households. An unconditional comparison of average energy intake of households living in districts with high and low shock intensity (above and below the 80th percentile of the distribution of standardised sheep mortality) does not show systematic patterns: against our expectations, calorie intake is not systematically lower in severely affected districts. This finding is also obtained when using different thresholds (85th or 90th percentile) to define severely affected districts. In contrast, total real consumption expenditures of both types of herding households get significantly lower in the second half of the year in districts with high shock intensity. This could suggest that exposure to the *dzud* leads to a longer-term reduction in consumption.

Table 2.6 displays the estimated coefficient of the shock intensity measure (standardised sheep mortality in 2002) obtained from estimating an extended version of Equation 2.2 with OLS. Note that this specification also includes month and province fixed effects, income, and the complete set of socioeco-

Table 2.6: The impact of *dzud* on the intake of nutrients

Dependent Variable	Calories	Carbo-hydrates	Animal proteins	Vegetal proteins	Animal fat	Vegetal fat	Iron	Vitamin A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Small-scale herding households								
Sheep losses in 2002	-0.042	-0.027	-0.047	-0.020	-0.128**	-0.029	-0.014	-0.014
	(0.032)	(0.031)	(0.044)	(0.031)	(0.058)	(0.064)	(0.032)	(0.033)
Income	0.152***	0.139***	0.159***	0.112***	0.202***	0.285***	0.114***	0.183***
	(0.013)	(0.013)	(0.021)	(0.014)	(0.025)	(0.029)	(0.016)	(0.027)
Share of calories from own animal husbandry	0.315***	-0.603***	2.435***	-0.943***	2.649***	-1.475***	-0.088	2.444***
	(0.08)	(0.087)	(0.127)	(0.086)	(0.118)	(0.161)	(0.09)	(0.156)
Consumed crops from own farming	0.046**	0.061***	-0.003	0.057**	-0.012	0.124**	0.033	0.006
	(0.022)	(0.023)	(0.032)	(0.025)	(0.034)	(0.052)	(0.025)	(0.037)
Income*Share of calories	-0.071	-0.021	-0.241**	0.013	-0.314***	0.126	0.081	-0.444***
	(0.063)	(0.066)	(0.104)	(0.068)	(0.107)	(0.111)	(0.077)	(0.128)
Income*Consumed crops	-0.032	-0.024	-0.018	-0.026	-0.023	-0.008	-0.041	0.016
	(0.025)	(0.025)	(0.035)	(0.025)	(0.039)	(0.052)	(0.025)	(0.041)
Sheep losses*Share of calories	-0.211**	-0.258***	-0.268*	-0.143	-0.079	0.024	-0.070	-0.343**
	(0.092)	(0.089)	(0.145)	(0.088)	(0.138)	(0.153)	(0.128)	(0.147)
Sheep losses*Consumed crops	0.008	0.008	0.010	-0.010	-0.031	-0.031	-0.044*	-0.013
	(0.029)	(0.026)	(0.043)	(0.028)	(0.062)	(0.061)	(0.026)	(0.039)
Number of households	1,267	1,267	1,265	1,267	1,265	1,266	1,267	1,266
R-squared	0.385	0.299	0.563	0.278	0.544	0.422	0.351	0.421
Panel B: Large-scale herding households								
Sheep losses in 2002	-0.021	-0.010	-0.005	0.000	-0.053*	0.040	-0.001	0.013
	(0.028)	(0.028)	(0.055)	(0.036)	(0.030)	(0.046)	(0.038)	(0.053)
Income	0.143***	0.122***	0.129***	0.102***	0.183***	0.311***	0.123***	0.113***
	(0.019)	(0.021)	(0.028)	(0.022)	(0.020)	(0.030)	(0.023)	(0.029)
Share of calories from own animal husbandry	0.358***	-0.821***	2.469***	-1.104***	2.901***	-1.712***	0.103	2.361***
	(0.115)	(0.119)	(0.184)	(0.151)	(0.166)	(0.241)	(0.159)	(0.199)
Consumed crops from own farming	0.028	0.034	0.028	0.045	0.026	0.121*	0.052	0.016
	(0.037)	(0.041)	(0.042)	(0.041)	(0.047)	(0.073)	(0.045)	(0.041)
Income*Share of calories	0.007	0.078	-0.001	0.095	-0.151	0.074	0.096	0.041
	(0.092)	(0.111)	(0.123)	(0.110)	(0.128)	(0.153)	(0.092)	(0.157)
Income*Consumed crops	0.002	0.007	0.010	0.014	-0.019	-0.074	-0.008	0.026
	(0.030)	(0.033)	(0.042)	(0.032)	(0.035)	(0.050)	(0.039)	(0.041)
Sheep losses*Share of calories	-0.067	-0.019	-0.090	0.041	0.263*	0.186	-0.126	-0.291
	(0.101)	(0.104)	(0.170)	(0.129)	(0.140)	(0.189)	(0.141)	(0.189)
Sheep losses*Consumed crops	0.002	0.003	-0.010	-0.001	-0.015	-0.024	-0.026	0.015
	(0.026)	(0.026)	(0.053)	(0.026)	(0.034)	(0.077)	(0.048)	(0.057)
Number of households	449	449	448	449	448	449	449	449
R-squared	0.461	0.388	0.592	0.358	0.653	0.47	0.453	0.546

Notes: All dependent variables and income are logarithmically transformed. All regressions include the complete set of controls as in Table 2.3. Displayed are coefficients estimated with OLS with *** $p<0.01$, ** $p<0.05$, * $p<0.1$ and standard errors in parentheses. For each household, two months of data from consumption diaries are used. Observations from February, April, July and October are excluded. Source: HIES/LSMS 2002/03.

nomic controls as discussed above.[10] We do not find evidence for a significantly negative effect of the *dzud* on the intake of calories. This holds for both small-scale and large-scale herding households.

However, for both small-scale and large-scale herders, the 2001/02 *dzud* had a significant and negative effect on the consumption of animal fat. For instance, a one standard deviation increase in *dzud* intensity decreases the intake of animal fat by 12.8 percent for small-scale herders with an average share of food self-provisioning. This could indicate that in times of stress, herders substitute away from the consumption of animal products in order to avoid depleting their herd further.

What is more,[11] the *dzud* effect on nutrient intake differs depending on how strongly a household relies on food self-provisioning. When looking at the marginal effects of the *dzud* on nutrient intake at different values of the food self-provisioning distribution (see Table A.2 in the Appendix), an interesting pattern emerges. Small-scale herders who consume less than a third of their calories from own production do not significantly change their nutrition patterns in response to the *dzud* (with the exception of animal fat). If the household however depends on food self-provisioning for its food consumption (meaning a calorie share from own production $>= 1/3$, which is the case for more than 25 percent of the small-scale herders in our sample), the *dzud* has a significantly negative effect on the intake of all macro- and micronutrients (with the exception of vegetal fat and iron). A one standard-deviation increase in *dzud* intensity decreases nutrient intake by 5 to 18 percent. This holds irrespective of whether the household also pursues farming activities or not. For large-scale herders on the other hand, there is no effect of the *dzud* on the nutrient intake observable,[12] regardless of how strongly the household depends on food self-provisioning. Hence, households who are already close to the subsistence level risk being unable to meet their basic consumption

[10]The magnitude and level of significance of these variables remain very similar after the inclusion of the shock measure.

[11]The following paragraph is not included in the published version of this chapter but was developed afterwards in preparation of a conference presentation.

[12]Again with the exception of animal fat.

needs in the aftermath of a shock.

Exposure to the shock also significantly affects the food self-provisioning-nutrition nexus. Again, this result is much more pronounced for small-scale herders. The interaction term between *sheep losses* and the *share of calories from own animal husbandry* is statistically significant for calories, carbohydrates, animal proteins, and vitamin A. Thus, for small-scale herders living in severely affected districts, the effect of food self-provisioning on the intake of calories, animal proteins, and vitamin A remains positive but is smaller in magnitude compared to small-scale herders living in unaffected districts. In contrast, the negative effect food self-provisioning has on the household's carbohydrate consumption is stronger in *dzud*-affected areas than unaffected areas. Overall, these correlations between shock intensity and food self-provisioning are only observable for the self-provisioning of meat and dairy products, but not for non-meat agricultural products. This suggests that the potential *dzud* effect manifests itself through household-level livestock losses.

2.6 Discussion

In this article, we use nationally representative household survey data from 2002/03 to investigate the role of food self-provisioning for the nutrient consumption of households in Mongolia. Our analysis distinguishes between the three prevalent Mongolian livelihoods: urban wage employees, rural households with small-scale animal husbandry activities, and pastoralist households owning large herds. Those three livelihood groups derive food from different sources, while they also face different degrees of market imperfections for food and agricultural output. Markets range from being close to perfect in urban areas to completely missing for some food groups in remote rural areas.

Results show that food consumption patterns differ significantly across the three livelihoods. We find that both small-scale and large-scale herding households consume significantly more of most nutrients than non-herding households. The wealth elasticity of nutrient intake is almost always statistically significant, positive, and remarkably similar across livelihood groups. The estimated elasticities for calories range between 0.15 to 0.18 for income, 0.36 to 0.43 for consumption expenditures, and amount to 0.03 for durables. An instrumental variables approach yields very similar estimates for both instrumented income and instrumented consumption expenditures, suggesting that results are not driven by reverse causality or correlated measurement errors.

Farming food crops improves the nutritional situation of small-scale herders and non-herding households. Their intake of calories and nutrients from vegetal sources is increased if they pursue small-scale agricultural production. In contrast, the provision of meat and dairy products through animal husbandry activities has ambivalent effects on the household's diet. On the one hand, the share of calories from own animal husbandry has a significantly positive effect on the intake of calories, vitamin A, and nutrients from animal sources of both small-scale and large-scale herding households.

Another positive aspect of food self-provisioning is that it significantly reduces income nutrient elasticities among small-scale herders and non-herding households, making food consumption patterns less dependent on short-term fluctuations in income. On the other hand, the share of food consumed from own meat and dairy production significantly decreases the intake of carbohydrates and nutrients from vegetal sources among herders. Thus, food self-provisioning seems to entail substitution effects that change the composition of the household's diet and, in turn, worsen the nutritional situation for those nutrients for which households already exhibit the greatest deficiencies. We interpret this finding in light of household-specific market failures caused by remoteness, which renders transportation costs to the next market prohibitively expensive.

Exposure to a severe shock – the extremely harsh 2001/02 winter that caused mass livestock death – does not reduce household calorie consumption on average. However, exposure to the shock significantly reduces the intake of animal fat for both types of herding households. The food self-provisioning-nutrition nexus also changes with *dzud* exposure: in *dzud*-affected areas, the positive effect of food self-provisioning on the intake of calories, animal protein and vitamin A is smaller compared to less exposed areas for small-scale herding households. This provides evidence for the hypothesis that households employ substitution strategies to keep overall energy intake constant if they are not strongly dependent on food self-provisioning for their consumption. However, small-scale herders relying on food self-provisioning significantly reduce the intake of macro- and micronutrients when affected by the extreme winter. This implies that households close to or at the subsistence level run the risk of being unable to meet their basic consumption needs in the aftermath of a shock.

Several policy implications can be drawn from our results, although one must keep in mind that the analysis presented here builds on data collected in 2002/03, which might not adequately reflect the nutritional situation of Mongolians in 2016. The most striking empirical finding of our study is the extent to which the diet of Mongolian households is unbalanced: the consumption of some micronutrients (especially animal fats) is as high as twice the recommended intake while the consumption of other nutrients (especially vegetal fats) is as low as one-third the recommended intake. The literature on health has shown robust evidence that both deficiencies and excess consumption of nutrients can have severe health impacts, particularly among children (Salois et al., 2012). What poses a challenge for policies is that the nutritional situation is rather different – with different nutrients being consumed too little or in excess – across herders and non-herders. Thus, any policies aiming to improve the nutritional situation of the population need to cater for the diverse livelihoods that follow distinct food consumption patterns.

Our results suggest five areas for potential interventions. First, income elasticities are highest for vegetal fat (0.29 to 0.30) and vitamin A (0.12 to 0.36), for which both herding and non-herding households have the lowest adequacy ratios. This suggests that income transfers could potentially improve the dietary quality of Mongolian households; especially for the poorest households. This result seems particularly interesting in light of the debate in Mongolia on the benefits of the food stamps programme and cash transfers made through the Human Development Fund of Mongolia. These programmes were launched by the Government of Mongolia in 2008 and 2009 but stopped in 2014 and 2013, respectively. Second, encouraging sedentary households to undertake backyard farming – even on a very small scale – appears to be an effective channel to ameliorate the consumption of nutrients from vegetal sources and carbohydrates. Third, in rural areas, shortages in the supply of fresh foods appear to be prevalent. Thus, enhancing the supply of foods that cannot be produced in the local climatic conditions is an area for policy interventions. Fourth, results suggest there could be scope for nutrition education programmes, as households with better educated women consume significantly more vegetal fats and vitamin A. Fifth, one potential area for intervention is to support herding households that suffered major livestock losses due to extreme climatic events and prevent those households from sacrificing food consumption. In recent years, such extreme weather events causing mass livestock mortality have occurred more frequently and with higher intensity – namely in the winters of 2009/10 and 2015/16. With climate change, this type of extreme weather event will likely occur even more frequently in the future.

Chapter 3

When Shocks Become Persistent: Household-Level Asset Growth in the Aftermath of an Extreme Weather Event[1]

with:
Kati Krähnert

Abstract

This chapter analyzes to what extent an extreme weather event can have persistent effects on household-level asset growth. Our focus is on the effect of a once-in-50-year winter disaster on post-shock livestock accumulation among pastoralists in Mongolia. Building on a novel household panel dataset, we investigate asset dynamics 2-5 years after the disaster occurred. Using a Hausman-Taylor estimator, we show that the extreme event has a significant, negative, economically large, and persistent effect on households' asset growth rates. Households seek to mitigate the shock effect by reducing their livestock offtake. This effort is counteracted by a large, negative, and persistent shock effect on livestock fertility. In addition, the intensity of the extreme weather event is a strong predictor for abandoning the herding economy, resulting in lower overall welfare. Our findings suggest that most households are unable to fully offset the effects of the weather disaster through their own coping behavior.
JEL codes: O12, O13, Q5

[1]This paper is in a revise and resubmit process at the *American Journal of Agricultural Economics.* Concerns raised by the reviewers are already addressed in the version presented here.

3.1 Introduction

With climate change, extreme weather events are becoming more frequent and severe, with detrimental effects for households. Between 1995 and 2015, weather-related disasters claimed more than half a million lives and affected more than 4 billion people worldwide (United Nations Office for Disaster Risk Reduction, 2015). Storms, floods, and cold waves often cause immediate asset losses, thus reducing household welfare. In addition, the loss of productive assets may reduce a household's future consumption and income-earning potential and, thus, its future welfare. Furthermore, if the effects of extreme weather events go beyond immediate impacts on current asset levels and also affect asset growth rates, shock effects may be perpetuated. Thus, a onetime shock might have prolonged adverse consequences for welfare dynamics. Given the covariate nature of extreme weather events, informal risk sharing arrangements are often ineffective (Barnett et al., 2008). In the absence of functioning formal insurance markets, a particular concern in developing countries, households may be even more likely to tear down their asset base in order to smooth consumption in the aftermath of a shock (Zimmerman and Carter, 2003; Rosenzweig and Wolpin, 1993). Understanding the impact of extreme weather events on households is a pressing policy question, given that such events are predicted to become more frequent in the future and their consequences are felt disproportionately more in developing countries (World Bank, 2010; Seneviratne et al., 2012).

Yet, little is known about the persistence of the effects of extreme weather events on households in developing countries. The existing literature on growth effects of extreme weather events and other natural disasters is narrow and focuses mainly on the country level (Cavallo et al., 2013; Felbermayr and Gröschl, 2014; Strobl, 2012; Kellenberg and Mobarak, 2011; Loayza et al., 2012). The few existing studies taking a household-level approach document that exposure to extreme weather events and other natural disasters adversely impacts human capital accumulation, child health, remittances, and income (Caruso and Miller, 2015; Gignoux and Menéndez, 2016; Groppo and Kraehnert, 2016, 2017). However, the impact of these events on household-level growth rates – and, in particular, asset growth – is not well understood. This gap in research is surprising, given the importance of assets in shaping households' long-term welfare dynamics (Dercon et al., 2012; Carter and Barrett, 2006; Sahn and Stifel, 2003).

This study aims to address this gap in the literature by analyzing how an extreme weather event shapes households' post-shock asset growth. Furthermore, our analysis explores the mechanisms underlying the observed growth outcomes. Our focus is on pastoralist households in Mongolia that lost a significant share of their livestock when a once-in-50-year winter disaster hit the country in 2009/10. Extremely cold temperatures and excessive snowfall caused the death of more than 10 million livestock, about 23 percent of the national stock. The quasi-experimental nature of the extreme winter – referred to as *dzud* in Mongolian – makes it an interesting study setting: the shock was severe, its intensity varied strongly across space, and households could hardly predict its occurrence (Murphy, 2011). The shock had detrimental effects for many pastoralist households, for whom livestock is by far the most important asset, causing widespread poverty, malnutrition, and rural-urban migration (Sternberg, 2010). Our empirical analysis builds on three waves of a representative household panel survey that we implemented in western Mongolia between 2012 and 2015, 2-5 years after the winter disaster. The econometric analysis uses the Hausman-Taylor panel estimator, which allows us to estimate the impact of the shock while controlling for unobserved household characteristics that are potentially correlated with past and current livestock holdings.

Findings indicate that the effects of the extreme weather event are indeed persistent: Household-level asset growth rates are negatively affected by the shock even several years after its occurrence. Available disaster coping strategies and emergency aid were ineffective in mitigating the negative growth effects of the extreme weather event. Households seek to mitigate the shock effects by reducing livestock offtake to preserve their asset level. This effort is counteracted by a negative, economically large, and persistent shock effect on livestock fertility. In addition, the intensity of the extreme weather event is a strong predictor for dropping out of the herding economy, which leads to lower overall welfare. Furthermore, smaller idiosyncratic shocks have significantly weaker effects on asset growth compared to the extreme weather event, indicating that shock persistence depends both on the severity and the covariate nature of the shock. Findings are robust to using different measures of shock intensity derived from various data sources.

Our study advances the existing household-level literature on growth in developing countries in several ways. Research in this area is limited – mainly due to a lack of adequate data – and typically focusses on income or consumption as opposed to asset growth (Jalan and Ravallion, 2002; Lokshin and Ravallion, 2004; Dercon et al., 2012). Further, there is some interest in the role of risk for growth (Elbers et al., 2007). However, shock persistence is typically not accounted for in standard empirical growth models, particularly at the household level, where shocks are generally only seen as a temporary setback (see Dercon, 2004 for a discussion; Barrett et al., 2006). We add to this literature by showing both theoretically and empirically how a one-off shock can have persistent effects on household asset dynamics even years after the shock occurred. Moreover, we provide novel insights into how households reconstruct their asset base in the aftermath of a shock. So far, only a few studies unravel what strategies households apply to recover from shock-induced losses, as such strategies are seldom recorded in standard household surveys.

Moreover, our study contributes to the literature on asset-based poverty traps (e.g. Carter and Barrett, 2006; Barrett and Carter, 2013). This literature assumes that a locally positive relationship between asset holdings and marginal returns to assets exists, which implies multiple asset equilibria toward which households converge in the long term. Yet, empirical evidence for such multiple equilibria is scarce (Kraay and McKenzie, 2014). Furthermore, the small number of studies within this literature specifically exploring how shocks influence household asset dynamics are often beset with endogeneity problems caused by the nature of the shock. For instance, slow-onset, prolonged droughts cause little destruction in assets per se, but rather affect household assets indirectly through income losses (Carter et al., 2007;

Giesbert and Schindler, 2012). Other studies focus on idiosyncratic shocks, such as illness and wedding expenses, which may strike some households with higher likelihood than others (Quisumbing and Baulch, 2013). In addition, most asset-based poverty traps studies mainly rely on nonparametric approaches (Carter and Barrett, 2006; Barrett and Carter, 2013; Naschold, 2012), thus leaving the underlying processes and the role of household heterogeneity unscrutinized. Our study expands this literature by documenting how household asset dynamics can be persistently shaped by a shock without requiring a framework of bifurcating asset dynamics. In addition, our focus on an extremely severe covariate shock that occurred over a short time period, immediately destroying household assets, allows for a straightforward identification of the shock effects, posing few endogeneity concerns. Moreover, the fundamental importance of livestock for the livelihood of Mongolian pastoralist as well as the ease with which it is observed greatly reduces measurement error problems inherent in studies that bundle various types of assets into one common index (Naschold, 2012; Michelson et al., 2013; McKay and Perge, 2013).

Lastly, our study contributes to the literature on welfare dynamics among pastoralists. Most existing studies are constrained by very small sample sizes, often less than 100 households (Lybbert et al., 2004; McPeak, 2006; Verpoorten, 2009). Some studies use time-series data on livestock obtained from a single survey interview during which households were asked about livestock transfers retrospectively, which renders checks on the quality of recall data difficult (e.g. Lybbert et al., 2004; McPeak, 2006). In contrast, our analysis builds on a sample of more than 850 pastoralist households that are representative of the population in the survey area. Moreover, data on livestock holdings is recorded from each household in three annual panel survey interviews in the post-shock period, while pre-shock herd size is asked retrospectively from households. This unique data allows us to observe households' asset growth over a medium-term time horizon.

The study proceeds as follows. Section 3.2 outlines the theoretical framework and section 3.3 introduces the household panel data and shock measures. Section 3.4 provides contextual information on the Mongolian herding economy. It then portrays the climatic conditions of the extreme winter of 2009/10 and shows that the intensity of the extreme event was the main determinant of livestock losses experienced by households. Sections 3.5 and 3.6 describe the identification strategy and the results, respectively. Section 3.7 concludes.

3.2 Asset growth under persistent shock effects: A theoretical framework

In this section, we propose a theoretical framework that outlines how the effects of a large covariate shock may become persistent. More specifically, the framework addresses two questions: (i) Can there be persistent effects of a large covariate shock on household-level asset growth even several years after the shock occurred; and, if so, (ii) how much of these effects is driven by a change in household behavior?[2] It seems intuitive that, in the case of serial dependence in asset growth, a shock influences the stock of assets and recovery is not immediate. However, the persistence of a shock effect on growth rates and the direction of such an effect is conceptually not straightforward.

Building on standard growth and intertemporal choice models (Deaton, 1991), we set up a simple quasi-autarkic model into which we directly include asset shocks. Similar to the model of McPeak (2006), our model is tailored to the specific case of livestock, which is not just a productive asset that is an investment and saving good, but one that simultaneously determines the household's future income and consumption potential. At the same time, it is not risk free.

The capital stock (livestock) of household i in period t is k_{it}. Changes in the capital stock from one period to the next when capital is not only an investment and production but also a consumption good are brought about by three factors: natural reproduction ($r(\cdot)$), shock-induced losses (θ_{it}), and ac-

[2] Directly and not just in expectations, as, for example, Elbers et al. (2007) analyze.

tive offtake (ot_{it}). Offtake is defined as the home consumption over the period $t-1$ to t. Reproduction $r(\cdot)$ of the capital stock is a function of the beginning-of-period stock (k_{it}) and shock effects (θ_{it}).[3] The reproduction function is concave in the capital stock and bounded below by the loss of the entire herd and above by natural limits to reproduction rates.

Households can directly consume their capital without transaction costs in the form of offtake (ot_{it}) from their herd and consumption of livestock by-products, the production of which are a function of the capital stock and labor input:[4]

$$c_{it} = ot_{it} + f(k_{it}, l_{it}) \tag{3.1}$$

Given the quasi-autarkic setting, there are no alternative income-earning activities into which households can invest and capital (livestock) is the only form to store wealth.[5]

Put together, capital in our model obeys the following law of motion:

$$k_{it+1} = k_{it} + r(k_{it}, \theta_{it}) + \theta_{it} - ot_{it} \tag{3.2}$$

Thus, the shock can have both a direct effect on the beginning-of-year stock in the post-shock period as well as an indirect reproduction effect on capital in the following period. Such an effect is expected if young or female animals have a disproportionally higher mortality risk than other animals or if fertility is lower in animals weakened by the shock.

The following equation illustrates how the effects of a shock can become persistent as a result of accumulating stock and reproduction effects and their

[3]Labor and land, household-specific herding skills, as well as geographic characteristics are assumed to be fixed. We abstract from those factors here but control for them in the empirical analysis below.

[4]For simplicity, we abstract from the fact that the shock may affect the production of by-products by weakening the livestock.

[5]Note the difference between the model developed here and standard buffer stock models (e.g. Fafchamps et al., 1998): Since income is derived entirely from livestock, households cannot use livestock to insure against fluctuations in income.

mutual feedbacks:

$$k_{it} = k_{i0} + \sum_{\tau=0}^{t-1} \theta_\tau - \sum_{\tau=0}^{t-1} ot_\tau + R(k_{i0}, \theta_{i0}, ..., \theta_{it-1}, ot_{i0}, ..., ot_{it-1}) \quad (3.3)$$

This is particularly likely for large covariate shocks, such as extreme weather events, which are intense and covariate, while their occurrence is difficult to predict for households. In line with Dercon (2004), if past shocks matter, then persistence is identified.

Furthermore, the household's offtake decision may also be persistently influenced by the shock experience. The following Bellman equation illustrates the household's decision problem and illustrates in which direction the shock effects could go (in line with standard notation, β is the personal discount factor and E the expectation operator):

$$V[k_{it}] \equiv \max_{ot_{it}} U(ot_{it} + f(k_{it}, l_{it})) + \beta E_t V[k_{it} + r(\cdot) + \theta_{it} - ot_{it}] \quad (3.4)$$

The household optimizes utility from consumption over time by choosing the optimal capital offtake. This results in the following first-order condition: $\frac{\partial U}{\partial c_{it}} = \beta E_t \frac{\partial V}{\partial k_{it+1}}$ and $\frac{\partial V}{\partial k_{it}} = \frac{\partial U}{\partial c_{it}} \cdot \frac{\partial f}{\partial k_{it}} + \beta E_t \frac{\partial V}{\partial k_{it+1}} \cdot (1 + \frac{\partial r}{\partial k_{it}})$. The former condition equates the marginal utility of one additional unit of consumption to the marginal value of keeping that unit for another period. The latter condition shows that the marginal value is equal to the contribution of the additional stock to current consumption (as livestock by-product) plus the expected discounted contribution to capital in the next period (including its contribution to herd reproduction).

Similarly, the marginal effect of a shock in the following period is $\frac{\partial V}{\partial \theta_{it}} = \beta E_t \frac{\partial V}{\partial k_{it+1}} \cdot (1 + \frac{\partial r}{\partial \theta_{it}})$ with $\frac{\partial r}{\partial \theta_{it}} > 0$ and $\frac{\partial \partial r}{\partial \partial \theta_{it}} < 0$ due to the concavity of the reproduction function. On the other hand, a shock that happened more than one period ago affects not only the value of future herd size, but also current consumption: $\frac{\partial V}{\partial \theta_{it-1}} = \frac{\partial U}{\partial c_{it}} \cdot \frac{\partial f}{\partial k_{it}} \cdot (1 + \frac{\partial r}{\partial \theta_{it-1}}) + \beta E_t \frac{\partial V}{\partial k_{it+1}} \cdot (1 + \frac{\partial r}{\partial \theta_{it-1}})$. Thus, the shock reduces current consumption of by-products, implying increased marginal utility of current consumption. By reducing the capital stock and reproduction, the shock also increases the marginal value of keeping the livestock for the next period, thereby increasing the opportunity cost of consumption. The overall effect depends on the relative importance of the consumption motif and the asset smoothing motif. As the effect could go in either direction, it needs to be determined empirically.

Next, we relax the autarky assumption and allow for interactions between households. This has two implications. First, households can sell livestock and livestock by-products to satisfy other consumption needs and they can purchase livestock to restock their herd. This enters the model in the form of a wider offtake notion ot_{it} that now comprises the combined consumption, investment, and sales decision. How would this affect the optimal offtake in response to a shock? If livestock prices were risky, the relative value of current compared to future livestock holdings and, thus, the optimal offtake at t would change. If households were able to anticipate their own shock losses, we would expect a household with high predicted losses to preemptively sell its livestock, even at the cost of lower prices and returns. Households with low predicted losses would be expected to postpone sales to the post-shock period to profit from increased demand and prices. Thus, the effects of a shock on optimal offtake depend on the intensity and duration of the shock as well as the level of market integration. Second, households can transfer assets with each other in the aftermath of a shock without price intermediation, for example in the form of informal insurance arrangements. Therefore, $nettransfers = transfersreceived - transfersgiven$ are added to the law of motion (equation 3.2), which then becomes $k_{it+1} = k_{it} + r(k_{it}, \theta_{it}) + \theta_{it} - ot_{it} + nt_{it}$ with transfers only occurring in the case of shock losses within the district (i.e.$nt_{it} = 0$ if $\theta_{it} = 0$ and if $\theta_{jt} = 0, \forall j = 1, ..., N_{district}$). The sign and magnitude of the net transfers depend on the relative magnitude of a household's own shock losses compared to the average shock losses experienced by households in the same district, which is influenced by the nature of the shock (covariate vs. idiosyncratic). In turn, total shock effects are expected to be weaker for affected households if the shock is not perfectly covariate.

From the theoretical framework, we deduct three hypotheses that are tested in the empirical part of the paper. First, both the optimal offtake decision and the natural reproduction in the post-shock period are influenced by the shock. This leads, second, to persistent effects on household-level asset growth that go beyond contemporary shock effects discussed in other studies. Third, the degree of shock persistence depends not only on the intensity of the shock, but also its covariate nature.

3.3 Data

The study builds on a novel panel dataset, the *Coping with Shocks in Mongolia Household Panel Survey*. The survey was collected by the authors and the National Statistical Office of Mongolia (NSO) between 2012 and 2015 and comprises three annual panel waves. Data collection took place in the provinces of Uvs, Zavkhan, and Govi-Altai in western Mongolia. The household survey covers 49 out of the 61 districts in the survey provinces.[6]

The survey was implemented on a rolling basis, with one twelfth of the sample households interviewed in each month. The data are also representative across seasons. Following the initial interview, each household was interviewed again exactly 12 months and 24 months later for the second and third survey waves. The first, second, and third panel waves were collected between June 2012 and May 2013, between June 2013 and May 2014, and between June 2014 and May 2015, respectively. This approach of implementing the household panel survey continuously for a total period of 36 months allowed us to employ the same field team throughout the entire survey period.

The Population and Housing Census, implemented November 11-17, 2010, provides the sampling frame. A multi-stage sampling design was employed to ensure that the survey is representative for urban areas and for rural areas in each of the three survey provinces. Each survey province was first subdivided into three mutually exclusive strata (province centers, district centers,

[6] A province (*aimag*) is the top level of Mongolia's administrative structure. Each province is subdivided into several districts (*soums*), which are further subdivided in sub-districts (*bags*). There are 21 provinces, 329 districts, and 1,720 sub-districts in Mongolia. As of 2011, districts in western Mongolia have an average population of 3,154 and a size of 4,811 km^2.

and rural areas). From these nine strata, 221 primary sampling units (PSU, the smallest population unit in Mongolia's administrative division) were randomly drawn. Eight households were then randomly selected from each PSU.

The total sample consists of 1,768 households interviewed in the first panel wave, comprising both non-herding and herding households. The analysis of post-shock asset growth presented here builds on a subsample of 855 herding households that owned livestock in 2009, just before the extreme winter, and at the time of each panel interview. Overall, panel attrition is negligible, with less than 2.15 percent of the entire sample dropping out of the survey between the first and third panel waves. The sample of pastoralist households reduces by 42 and 30 herding households in the second and third panel waves, respectively. The majority of those households stopped herding activities and no longer owned any livestock, while 3 and 6 households could not be reinterviewed in the second and third panel waves, respectively.

The survey consists of a household questionnaire, a district questionnaire capturing infrastructure and population characteristics, as well as a district price questionnaire. In addition to recording standard demographic and socioeconomic characteristics, the household questionnaire collects detailed information on the migration history of adult household members, including the district of birth and the district of residence just before the unfolding of the extreme winter of 2009/10. Moreover, it records the employment history of the head of household and his/her spouse as well as the occupation of the head's parents.

The questionnaire module on livestock records detailed information on households' livestock holdings at the time of each survey wave. This includes the total number of animals owned by the household, the number of reproductive female animals, and the number of newborn animals younger than one year, separately for each of the common five species (horses, cattle, camels, sheep, and goats). In addition, changes in households' livestock holdings over the past 12 months were recorded, again by species. Information is available on the number of animals purchased, sold, self-consumed by the household, received as in-kind wage income, inherited, received as remittances, sent as remittances, as well as the number of animals lost due to attacks by wild animals, livestock diseases, and theft. Currently, Mongolian pastoralists do not pay any livestock taxes. Hence, we do not expect survey respondents facing systematic incentives to underreport their true livestock holdings during the survey interview.

Another questionnaire module asked households retrospectively for their pre-shock livestock holdings (in 2009) and shock-induced losses (in 2010). This retrospective information was recorded twice, in the first panel wave and then again in the third panel wave. The livestock numbers reported by households were remarkably similar across the two waves, giving us confidence that herders have a good account of their past herd size even several years ago. However, a sizable number of households only reported livestock holdings in 2009 and/or livestock losses in 2010 in terms of total herd size, but not disaggregated by livestock species. It is common for Mongolian herders to only refer to the absolute number of livestock when speaking about herd size. This is also reflected in language: While there are specific terms in Mongolian for herders having a herd size of <100 heads, 100-200 heads, 200-500 heads, 500-1,000 heads, and >1,000 heads, all of those terms relate to total herd size, irrespective of the species (Murphy, 2011). In the Mongolian context, this is reasonable: Given the extreme remoteness of Mongolia's countryside, most herders spend many months of the year in isolated campsites. Hence, herders need to maintain a mix of several species that complement each other in terms of by-products and utility. Consequently, herd composition does not differ dramatically across pastoralist households.[7] Thus, we use total herd size – treating animals of different species as equal – in our main analysis.

We complement the household survey data with two sources of secondary data to measure spatial variation in shock intensity. First, we draw on aggre-

[7]To a limited extent, local environmental conditions also affect the herd mix. For instance, herders in desert areas tend to have fewer cattle, while herders living in forest and mountain areas tend to have fewer camels. We control for the impact of environmental conditions in the empirical analyses presented below with either district-level controls for the ecological zone or district fixed effects.

gated data from the annual Mongolia Livestock Census, which has been implemented since the 1950s. Each year in mid-December, the NSO gathers data on herders' livestock holdings as well as livestock losses experienced in the past 12 months, separately for each species. This exercise is carried out collaboratively by enumerators and local officials, who maintain detailed records of herders and their livestock in their administrative division. From the Mongolia Livestock Census data, we construct aggregate measures of the mortality of adult animals in 2010 at the level of the district and the sub-district.

Second, we measure shock intensity with data on temperature from the ERA-Interim model outputs of the European Centre for Medium-Range Weather Forecasts. We use the average temperature at earth skin at midnight in each sub-district between December 20, 2009 and February 10, 2010, the time referred to as "cold period" in Mongolia. This average temperature during the 2009/10 winter is then standardized by subtracting the mean and dividing it by the standard deviation of the long-term average midnight temperature in each sub-district during the same period (mid-December until mid-February) between 1991 and 2008. We aggregate sub-district data to the district level by assigning each district the value of the sub-district with the most extreme deviation.

Furthermore, we employ district-level data on the total amount of emergency aid delivered to households in 2010. The district-level dataset was compiled by the Mongolian Red Cross Society (MRCS), which was one of the key actors delivering aid during the winter disaster. The dataset comprises of aid provided by the central government, provincial governments, and NGOs. Information is available on the amount of food aid and animal fodder (in tons) distributed in each district directly after the shock.

3.4 The empirical context: Pastoralism in a risky environment

3.4.1 Herding in Mongolia

Herding plays a vital role in the Mongolian economy. In 2012, it engaged 35 percent of the workforce, while 19 percent of the population depended on herding for their livelihood (National Statistical Office of Mongolia, 2013). For pastoralist households, livestock not only provides meat, milk, and other dairy products for daily consumption, but it is also a source of cash income through the sale of livestock or livestock by-products. Herders typically own a mix of horses, cattle, camels, sheep, and goats. A herd size of 100-150 animals (irrespective of the species) is typically considered to be the minimum needed in order to maintain a herding livelihood in Mongolia (Goodland et al., 2009).

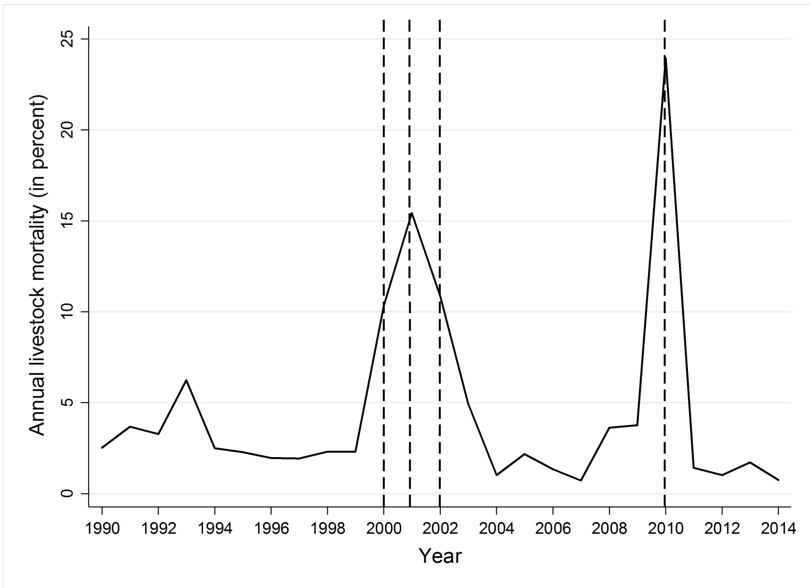
For the vast majority of households owning livestock, the stock of animals is by far the single most important asset. The value of livestock holdings amounts to 90 percent of the total value of all assets owned (evaluated at current sales prices) for the median household in our sample of pastoralists. Further, asset accumulation over time can be attributed almost entirely to livestock growth: median growth rates in livestock value are ten times larger than median growth rates in the value of non-livestock asset holdings.

In most parts of the country, the climate is not suitable for hay or fodder production. Thus, animals need to be grazed year-round. Herding typically involves extensive production techniques with grazing taking place on open rangelands that are state property. Most pastoralist households follow a nomadic or semi-nomadic lifestyle, moving their herds between 2 and 25 times per year, mainly in spring, summer, and autumn. Herders generally follow the same movement patterns every year as pasture access rights are regulated by a complex system of norms and customary law (Fernández-Giménez, 1999). Households underline their claims on particular campsites by investing in shelters or wells, which are considered private property. Use rights over camp sites are often passed on from generation to generation (ibid.).

3.4.2 The 2009/10 extreme winter

Unusually harsh winters present the greatest threat to herders. *Dzuds* are caused by a complex interplay of several unfavorable climatic conditions that reinforce each other, while the exact triggering conditions can differ across *dzuds*. They have in common that they cause sudden and mass livestock mortality, thus directly impairing the very livelihood of herding households. Since 1990, there have been four major *dzuds* in the winters of 1999/00, 2000/01, 2001/02, and 2009/10. The *dzud* of 2009/10 – which is the focus in this study – caused the largest livestock losses in a single winter in the past 50 years, with national-level livestock mortality amounting to more than 23.9 percent (see Figure 3.1). Among sample households included in our panel survey, the average livestock mortality was 43 percent (see Table 3.1).

Figure 3.1: Annual livestock mortality in Mongolia, 1990-2014



Notes: Livestock include camels, cattle, horses, sheep, and goats. Only deaths of adult livestock are considered. Dashed lines indicate *dzud* years. Source: Authors' calculations based on the Mongolia Livestock Census.

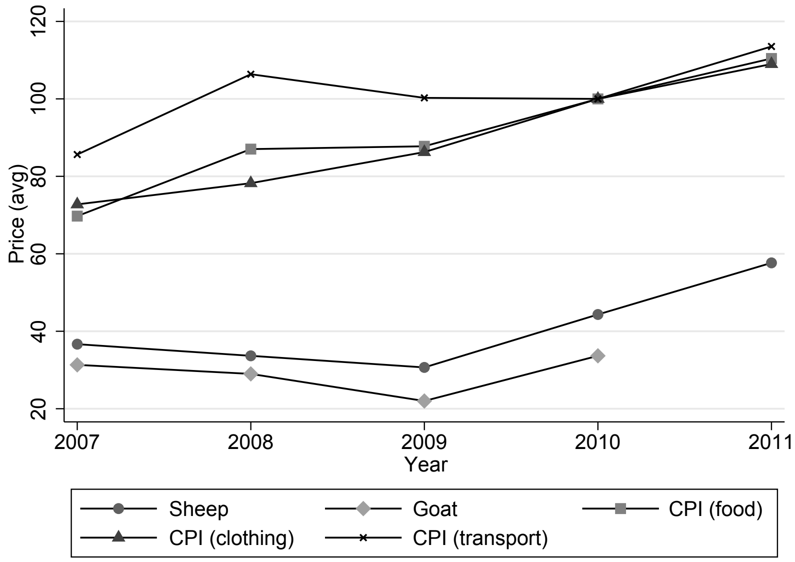
Unfavorable weather conditions began in summer 2009, when below-average rainfall caused poor pasture conditions and prevented animals from building up enough fat reserves.[8] This was followed by early and heavy snowfalls in October 2009, impeding animals from reaching the grass and causing animal starvation. Conditions worsened even more with record low temperatures in December 2009 and January 2010, freezing weakened animals to death. Finally, snowmelt in May 2010 resulted in flash floods that further damaged livestock. In January 2010, the Government of Mongolia declared a national disaster and called for international support (International Federation of Red Cross and Red Crescent Societies (IFRC), Mongolian Red Cross Society (MRCS), 2010). Distribution of emergency aid to affected households started in March 2010.

Formal insurance opportunities were very limited in rural Mongolia in 2009, just prior to the shock analyzed here. Herders mostly relied on informal risk-management strategies (Skees and Enkh-Amgalan, 2002). Increasing the herd size is the most important informal risk management strategy to prepare for harsh winters (Goodland et al., 2009). Common short-term strategies applied in the midst of extreme winters include conducting additional nomadic movements and purchasing supplementary fodder (Fernandez-Gimenez et al., 2015; Murphy, 2011). However, informal risk management mechanisms often fail to work well in the presence of severe covariate shocks. Consequently, "high levels of livestock mortality are often unavoidable even for the most experienced herders" (Mahul and Skees, 2007, p.10). After an extreme winter, restocking is the most important goal for herders (Goodland et al., 2009).

Precautionary livestock sales at the beginning of a *dzud* winter are not a major strategy applied by Mongolian pastoralists, at least not in the survey region. If such sales took place on a large scale, one would expect livestock prices to sharply drop during *dzud* years. Yet, Figure 3.2 shows that this was not the case: In the survey region, prices for sheep and goats – the most commonly consumed types of meat – followed similar trends over the 2007-2011

[8]For a detailed account of the climatic conditions during the 2009/10 *dzud*, see Groppo and Kraehnert (2017, p.441).

Figure 3.2: Average prices of livestock and other consumption goods in western Mongolia, 2007-2011



Notes: Average annual prices (in Mongolian Tugrik) in provincial centers in the survey area (Uvs, Zavkhan, and Govi-Altai provinces). The base year for the consumer price indices is 2010. Source: Authors' calculation based on the Mongolian Statistical Yearbooks.

period as the consumer price index of various other consumption goods.[9] There are also no excessive price increases in the aftermath of the shock that would incentivize postponed sales. We suggest that the lack of precautionary livestock sales at an early phase of the 2009/10 *dzud* is due to two reasons: First, it mirrors the unpredictability of the extreme weather event and subsequent livestock mortality to pastoralists. Second, livestock markets are poorly integrated and only exist in provincial centers. Given the remoteness of the countryside, pastoralist households live up to 380 kilometers from the next provincial center, thus incurring high transportation costs. In average years, households tend to sell their livestock in bulk during the summer months (Murphy, 2011). During *dzud* winters, the snow cover on the ground and extremely low temperatures make transport of livestock to urban centers even more difficult and often prohibitively expensive. The lack of precautionary

[9] In addition, since livestock is a consumption good itself, households can always transform livestock into (food) consumption at no cost. Price risk is therefore unlikely to be an issue in the present setting.

livestock sales among Mongolian pastoralists contrasts with findings from other empirical contexts, where distress sales during or shortly after shocks at unfavorable prices are identified as a particularly damaging shock coping strategy (e.g. Fafchamps et al., 1998; Janzen and Carter, 2013; Verpoorten, 2009).

3.4.3 Explaining household-level livestock mortality

Next, we investigate the direct effect of the 2009/10 extreme winter on the livestock mortality experienced by households in 2010, using the *Coping with Shocks in Mongolia Household Panel Survey* data. Given the severity of the *dzud* and the short time period over which it occurred, we hypothesize that livestock losses experienced by sample households are largely explained by the extreme weather event, while we expect household-specific characteristics and behavior to have little explanatory power.

To test this hypothesis, we regress household-level livestock mortality in 2010 on objective measures of *dzud* intensity, household, herd and district controls, as well as province fixed effects as follows:

$$\begin{aligned} m_{ij2010} =& \beta_1 dzudintensity_{j2010} + \beta_2 herdcharacteristics_{ij2009} + \beta_3 experience_{ij} \\ &+ \beta_4 volatility_j + \beta_5 coping_{ij2010} + \beta_6 X_{ij} + \eta_p + \epsilon_{ij} \end{aligned} \tag{3.5}$$

Livestock mortality m_{ij2010} of household i living in district j is defined as the proportion of the number of animals lost by the household in 2010 relative to the household's herd size just prior to the shock. $Dzudintensity_{j2010}$ is measured by the district-level livestock mortality in 2010, derived from the Mongolia Livestock Census. Given that this measure is calculated from the entirety of herders in a given district, potential measurement errors in the household-level and district-level mortality should be uncorrelated. As alternative measures of *dzud* intensity, we employ livestock mortality in 2010 at the sub-district level, again derived from the Mongolia Livestock Census, as well as district-level standardized winter temperature (see section 3.3). To account for nonlinearities, the square of the standardized temperature measure is also included.

The vector *herdcharacteristics*$_{ij2009}$ captures various characteristics of the herd in 2009, just prior to the extreme weather event. Most importantly, this includes a household's livestock holdings. Rejection of the null hypothesis of $\beta_2 = 0$ in favor of a negative coefficient would indicate that households with smaller herds are hit proportionally harder by the *dzud*. Furthermore, livestock mortality may vary with herd composition if, for example, small ruminants are more vulnerable to extreme winter conditions. Therefore, we also control for the share of goats in the household's herd as of 2009.

Herders' *experience*$_{ij}$ might play a role in determining shock losses. Proxies for experience include whether the parents of the household head were herders, whether the head always lived in his/her district of birth, and whether the household was already engaged in herding in 1999, just before *dzuds* occurred in three consecutive winters between 2000 and 2002. These variables should capture the effects of both herding skills as well as pasture use rights and herder networks that are passed on across generations.

In addition, we control for the long-term *volatility*$_j$ in livestock growth at the district level by including the standard deviation of the annual livestock population between 1991 and 2009, calculated from Mongolia Livestock Census data. Rejecting the null hypothesis of $\beta_4 = 0$ in favor of a negative coefficient would suggest that herding households living in districts that were exposed to greater volatility in livestock growth in the past might have developed strategies to reduce their vulnerability to the 2009/10 *dzud*.

Moreover, we test whether shock *coping*$_{ij}$ strategies applied during the *dzud* influenced livestock losses experienced by households. Proxies for coping strategies include whether the household conducted additional movements with their herd during the winter months (*otor* in Mongolian) and whether the household sold livestock.

The vector X_{ij} captures further household-level and district-level controls.

Table 3.1: Summary statistics - Part A

Variable	Mean	Std. Dev.	Min.	Max.	N
Outcome					
Household-level livestock mortality in 2010, in percent	0.43	0.23	0	1	1,079
Abandoning herding after the *dzud*	0.06	0.23	0	1	1,079
Dzud intensity					
Livestock mortality in 2010 per district, in percent	0.33	0.12	0.12	0.61	1,079
Livestock mortality in 2010 per sub-district, in percent	0.34	0.13	0.04	0.76	1,079
Standardized winter temperature per district	-1.13	0.45	-2.2	-0.43	1,079
Mortality covariance (within-district standard deviation)	0.25	0.07	0.01	0.72	1,079
Percent of households per district with zero *dzud* losses	0.05	0.08	0	0.33	1,079
Pre-shock herd characteristics					
Herd size in 2009	288.8	215.35	2	1800	1,079
Herd size in 2000	286.5	185.79	0	1449	643
Share of goats in 2009	0.38	0.21	0	1	934
Household achieved full recovery after the 2000-2002 *dzuds*	0.57	0.45	0	1	641
Experience					
Parents of head were herders	0.94	0.23	0	1	1,073
Head always lived in current district	0.82	0.36	0	1	1,079
Household was herding during the 2000-2002 *dzuds*	0.85	0.33	0	1	1,079
Volatility					
Std. dev. of annual livestock population per district, 1991-2009	8.99	3.27	2.15	16.14	1,079
Shock coping					
Household went on temporary migration during *dzud*	0.20	0.38	0	1	1,062
Household sold livestock	0.13	0.31	0	1	1,062
Tons of food aid and animal fodder per herding household per district	0.05	0.04	0	0.19	1,079
Household and district characteristics					
Age of head	43.52	10.66	16	87	1,079
Female head	0.08	0.25	0	1	1,079
Secondary or higher education	0.63	0.45	0	1	1,079
Head was full-time herder in 2009	0.77	0.39	0	1	1,079
Spouse was full-time herder in 2009	0.65	0.45	0	1	1,079
Household lived in rural area in 2009	0.73	0.42	0	1	1,079
Stocking density (livestock in log per km^2) per district	3.64	1.09	1.67	8	1,069
Ecological zone of district is mountain steppe	0.33	0.44	0	1	1,079
Ecological zone of district is forest steppe	0.14	0.32	0	1	1,079
Ecological zone of district is grass steppe	0.25	0.40	0	1	1,079
Ecological zone of district is desert steppe or desert	0.28	0.42	0	1	1,079
Province					
Zavkhan	0.34	0.44	0	1	1,079
Govi Altai	0.29	0.43	0	1	1,079
Uvs	0.37	0.45	0	1	1,079

Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, ERA-Interim, and MRCS emergency aid data.

These include the age of the household head, whether the household head is female, whether at least one household member completed secondary or higher education, whether the household head as well as the spouse reported herding as their main income earning activity in 2009, and whether the household lived in a rural area just before the shock. Given that geographic factors such as vegetation, wind exposure, and slope influence *dzud* intensity, we control for the dominant ecological zone in the district (mountain steppe, forest steppe, grassland, and desert steppe/desert). Mortality may also depend on the local stocking density if overgrazing had prevented animals from building up sufficient fat reserves during the summer. We capture this possibility by controlling for livestock density by district in 2009, calculated as the number of livestock (in log) per km^2. Lastly, province fixed effects η_p control for any differences across the three survey provinces. We estimate the model by fitting a generalized linear model with a logit link function to account for the fact that the outcome is a proportion. Summary statistics of all outcome and control variables can be found in Table 3.1.

Results displayed in Table 3.2, column 1 show that *dzud* intensity has a significant and large effect on household-level livestock mortality in 2010. A 10 percentage point increase in the district-level livestock mortality increases household-level livestock mortality by about 6.8 percentage points. This finding is robust to measuring *dzud* intensity with livestock mortality at the sub-district level (column 2) and with winter temperature (column 3).[10] In contrast, pre-shock herd size does not significantly influence household-level livestock mortality: wealthier and poorer herders before the shock lost a similar share of their livestock during the *dzud* (column 1). Only households with large herds of 100 heads and more experienced a 7-8 percentage

[10]Marginal effects are negative at the 10th percentile of the winter temperature distribution and positive above the 50th percentile. This implies an increase in the mortality rate with increasing temperatures in the upper half of the temperature distribution. This is likely due to the fact that "warmer" winter temperatures are correlated with higher snowfall. An exact modelling of livestock losses using climate data is beyond the scope of this paper, as *dzud* winters are characterized by a complex combination of different climatic phenomena. Therefore, we abstain from interpreting the point estimates on the winter temperature coefficients. Instead, we take the significant influence of winter temperature on household-level livestock losses as further support of our hypothesis that losses are driven by factors beyond the scope of the household's actions.

points higher livestock mortality compared to households with small herds (column 4), which may mirror the lower livestock to labor ratio in wealthier households. Herd composition, measured by the share of goats in the herd directly before the shock, does not significantly affect household-level livestock mortality (column 5), neither does overgrazing in the district significantly influence mortality (column 6).

Similarly, herding experience does not significantly affect household-level livestock mortality in 2010. Even if the head of household grew up in a herding household and, thus, most likely experienced previous *dzud* events, this did not provide him or her with additional knowledge or skills that could have helped minimizing shock exposure (Table 3.2, column 1). Nor did herders residing in their native district benefit from better herder networks or more secure pasture use rights. We only find a significant effect of experience when directly controlling for whether the household was herding already during the triple *dzud* winters between 2000 and 2002 (column 7): Having experienced these previous *dzud* events reduces losses due to the 2010 *dzud* by 7 percentage points. Herders living in a district that faced higher volatility in livestock growth between 1991 and 2009 do not differ significantly in their livestock mortality from herders exposed to lower previous livestock volatility.

Similarly, the shock coping strategies chosen by the household – going on temporary migration during the *dzud* or purchasing animal fodder (column 8) – do not significantly affect livestock mortality in 2010. Most household-level characteristics do not have a significant effect on household-level livestock mortality either. Two exceptions are households headed by a woman and households in which the head was not a full-time herder in 2009, directly before the *dzud* (Table 3.2, column 1); both characteristics are associated with higher household-level mortality. Recall that all results presented so far rely on total herd size, treating animals of different species as equal, which is common in Mongolia. As additional robustness test, we transform the outcome variable into horse units,[11] the conversion rate commonly used in Mongolia. Table B.1 in the Appendix displays estimates obtained for the subsample of

[11]One horse unit is equivalent to one cow, 0.67 camels, six sheep, or eight goats.

882 households that reported 2009 livestock holdings and 2010 livestock losses by species. Results are similar to the baseline findings.

Put together, these results confirm our hypothesis that livestock losses experienced by households are largely exogenously determined by weather conditions during the *dzud* and unaffected by household characteristics or coping behavior. Nevertheless, the *dzud* was not perfectly covariate either, given that district-level livestock mortality does not fully translate into household-level livestock mortality.

Table 3.2: Determinants of household-level livestock mortality in 2010 (Generalized linear model using the logit link)

	Outcome: Household-level livestock mortality in 2010, in percent							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dzud intensity								
Mortality (district)	0.68***			0.69***	0.71***	0.67***	0.68***	0.70***
	(0.069)			(0.069)	(0.070)	(0.069)	(0.069)	(0.069)
Mortality (sub-distr.)		0.42***						
		(0.054)						
Winter temperature (district)			0.34***					
			(0.091)					
Winter temperature squared			0.13***					
			(0.036)					
Pre-shock herd characteristics								
Herd size in 2009 (in log)	0.01	0.02*	0.01		0.01	0.01	0.02*	0.01
	(0.010)	(0.010)	(0.010)		(0.011)	(0.010)	(0.010)	(0.010)
Herd size in 2009 btw 50 and 99				0.03				
				(0.044)				
Herd size in 2009 btw 100 and 199				0.07*				
				(0.040)				
Herd size in 2009 greater 199				0.08**				
				(0.038)				
Share of goats in 2009					0.04			
					(0.041)			
Experience								
Parents of head were herders	-0.03	-0.04	-0.03	-0.04	-0.01	-0.03	-0.03	-0.03
	(0.038)	(0.040)	(0.039)	(0.039)	(0.044)	(0.039)	(0.039)	(0.039)
Head always lived in current district	-0.02	-0.06**	-0.05**	-0.02	-0.01	-0.01	-0.02	-0.03
	(0.021)	(0.022)	(0.022)	(0.021)	(0.024)	(0.023)	(0.021)	(0.022)
Head was full-time herder in 2009	-0.07**	-0.07**	-0.07**	-0.08***	-0.05	-0.07**	-0.04	-0.06**
	(0.029)	(0.029)	(0.029)	(0.029)	(0.033)	(0.029)	(0.030)	(0.029)
Spouse was full-time herder in 2009	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02
	(0.022)	(0.022)	(0.022)	(0.022)	(0.024)	(0.022)	(0.022)	(0.022)
Herding during the 2000-2002 *dzuds*							-0.07**	
							(0.028)	
Shock coping in 2010								
Temporary migration								0.00
								(0.017)
Household sold livestock								-0.03
								(0.020)
Volatility and stocking density								
Volatility in livestock population (distr.)	0.00	0.00	0.01***	0.00	-0.00	0.00	0.00	-0.00
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Stocking density (district)						0.01		
						(0.007)		
Household characteristics								
Age of head	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Female head	0.10***	0.10***	0.10***	0.10***	0.10***	0.10***	0.11***	0.09***
	(0.031)	(0.031)	(0.032)	(0.032)	(0.034)	(0.031)	(0.031)	(0.031)
Secondary or higher education	-0.03	-0.03	-0.03**	-0.03*	-0.03	-0.03	-0.03*	-0.03
	(0.016)	(0.016)	(0.016)	(0.016)	(0.017)	(0.016)	(0.016)	(0.016)
Lived in rural area in 2009	0.02	0.02	0.01	0.01	-0.01	0.02	0.02	0.02
	(0.021)	(0.022)	(0.023)	(0.021)	(0.023)	(0.021)	(0.021)	(0.021)
District characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	Province	Province	Province	Province	Province	Province	Province	Province
Observations	1,073	1,073	1,073	1,073	931	1,063	1,073	1,056

Model estimated as generalized linear model using the logit link. The table reports marginal effects obtained using the delta method and standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%, ** significant at 5%, *** significant at 1%. In column 4, the excluded category is herd size in 2009 between 1 and 49 animals. Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, and ERA-Interim data.

3.5 Post-shock asset growth: An empirical investigation

3.5.1 Households that abandoned herding after the 2009/10 extreme winter

In the theoretical discussion above, we show that exposure to a large covariate shock can affect households beyond the direct and immediate loss of assets. As a first approach to evaluating empirically the persistence of shock effects, we focus on households that abandoned herding in the aftermath of the 2009/10 extreme winter. Given the harsh continental climate in Mongolia, farming is unfeasible in most areas and employment opportunities are virtually nonexistent in rural areas. Thus, most households dropping out of the herding economy in the aftermath of the shock move to district or provincial centers and earn income through other activities. In the sample studied in this paper, 13 percent of the households that owned livestock in 2009 abandoned herding after the *dzud*.[12]

[12] Recall that the sample is representative of the population in western Mongolia as of November 2010, when the Population and Housing Census was implemented. Hence, our database misses households that moved to other provinces or the capital Ulaanbaatar immediately following the *dzud*. Yet, neighboring provinces lack employment opportunities, while the distance between the survey area and Ulaanbaatar is more than 1,000 km. Hence, we do not consider it likely that such movements occurred quickly after the *dzud*.

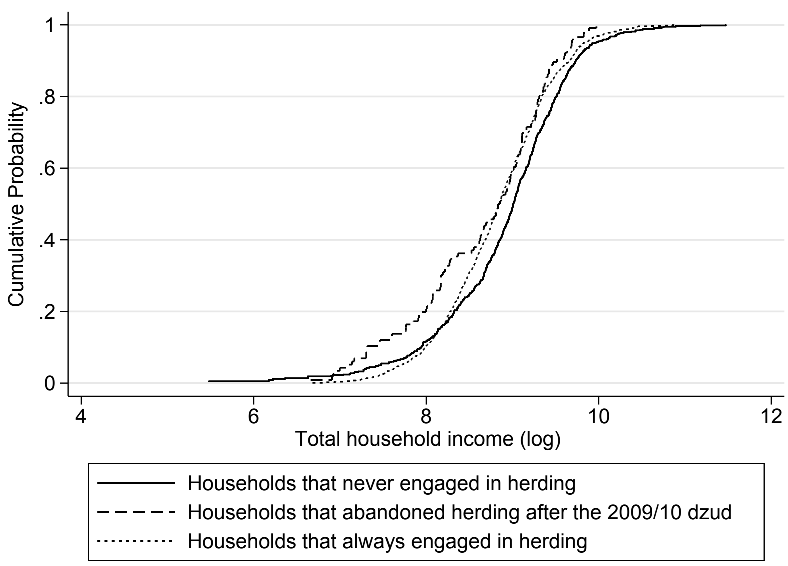
Table 3.3: Determinants of abandoning herding in the aftermath of the *dzud* (Probit)

	Outcome: Household abandoned herding after the shock						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dzud intensity							
Livestock mortality (household)	0.14***			0.12***	0.13***	0.14***	0.14***
	(0.016)			(0.014)	(0.016)	(0.016)	(0.016)
Livestock mortality (district)		0.20***					
		(0.047)					
Winter temperature (district)			0.26***				
			(0.056)				
Winter temperature squared			0.11***				
			(0.024)				
Pre-shock herd characteristics							
Herd size in 2009 (in log)	-0.02***	-0.02***	-0.02***	-0.02***	-0.02***	-0.02***	-0.02***
	(0.005)	(0.005)	(0.006)	(0.004)	(0.005)	(0.005)	(0.005)
Share of goats in 2009				-0.01			
				(0.014)			
Experience							
Parents of head were herders	-0.04***	-0.05***	-0.06***	-0.03***	-0.04***	-0.04***	-0.04***
	(0.012)	(0.012)	(0.013)	(0.009)	(0.011)	(0.012)	(0.011)
Head always lived in current district	-0.04***	-0.05***	-0.05***	-0.03***	-0.03**	-0.04***	-0.04***
	(0.010)	(0.011)	(0.011)	(0.007)	(0.011)	(0.010)	(0.010)
Head was full-time herder in 2009	-0.03***	-0.05***	-0.06***	-0.01	-0.03***	-0.03**	-0.03***
	(0.011)	(0.013)	(0.014)	(0.009)	(0.011)	(0.012)	(0.011)
Spouse was full-time herder in 2009	-0.04***	-0.05***	-0.06***	-0.03***	-0.04***	-0.04***	-0.04***
	(0.012)	(0.015)	(0.016)	(0.012)	(0.012)	(0.012)	(0.012)
Herding during the 2000-2002 *dzuds*						-0.01	
						(0.012)	
Shock coping in 2010							
Temporary migration							0.02*
							(0.009)
Household sold livestock							0.00
							(0.012)
Volatility and stocking density							
Volatility in livestock population (distr.)	-0.00	-0.00	-0.00	-0.00*	-0.00	-0.00	-0.00
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Stocking density (district)					0.01**		
					(0.004)		
Household characteristics							
Age of head	0.00	0.00	0.00	-0.00	0.00	0.00	0.00
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Female head	-0.01	0.01	0.01	0.00	-0.01	-0.01	-0.01
	(0.013)	(0.016)	(0.016)	(0.009)	(0.012)	(0.013)	(0.013)
Secondary or higher education	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01
	(0.011)	(0.012)	(0.012)	(0.009)	(0.011)	(0.011)	(0.011)
Lived in rural area in 2009	0.00	0.01	0.00	-0.03***	0.00	0.00	0.00
	(0.011)	(0.012)	(0.012)	(0.010)	(0.011)	(0.011)	(0.011)
District characteristics	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	Province	Province	Province	Province	Province	Province	Province
Observations	1,073	1,073	1,073	931	1,063	1,073	1,056

Model estimated with probit. The table reports marginal effects and standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%, ** significant at 5%, *** significant at 1%. Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, and ERA-Interim data.

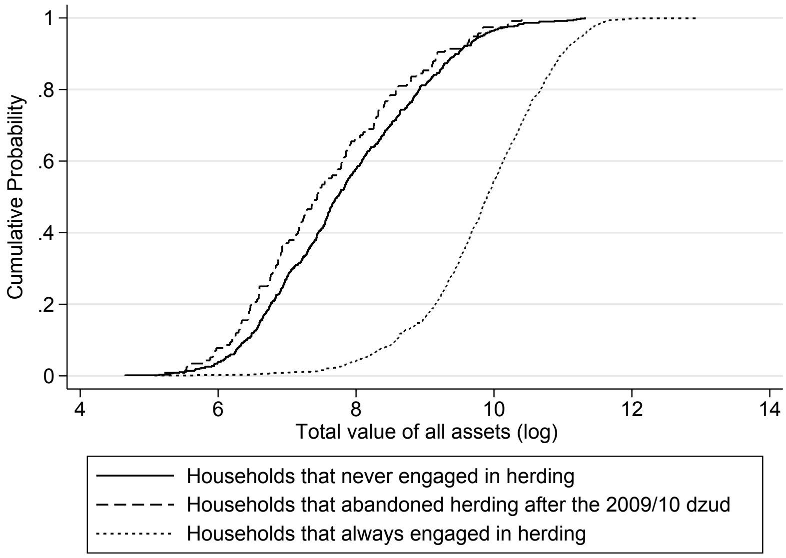
We first investigate the determinants of abandoning herding after the 2009/10 *dzud*. To do so, we estimate the probability of owning no livestock during all three panel waves (2012-2015) as a function of pre-shock livestock holdings, shock losses, as well as household, herd, and district characteristics prior to the shock with a probit regression. Results displayed in Table 3.3 show that the livestock mortality experienced by the household in 2010 is the single most important predictor for dropping out of herding. An increase in livestock mortality by 10 percent increases the likelihood of abandoning herding by 1.4 percent (column 1). This finding is robust to measuring shock intensity with district-level livestock mortality (column 2) and district-level winter temperature (column 3). When both head and spouse were full-time herders prior to the shock, when the head always lived in the current district as well as a large pre-shock herd size have a significant, but economically small, mitigating effect on the likelihood of abandoning herding in the aftermath of the shock. On the contrary, having been a herder throughout the triple *dzuds* of 2000-2002 does not significantly affect post-shock outcomes (column 6). Results are robust to using a less strict definition of the outcome variable, where we also count the 29 households as "dropouts" who reported zero livestock holdings in the first panel interview but had restarted herding when interviewed during the second or third panel waves.

Figure 3.3: Cumulative distribution of total household income, by herding status in 2012



Source: Coping with Shocks in Mongolia Household Panel Survey.

Figure 3.4: Cumulative distribution of the total value of all household assets, by herding status in 2012



Source: Coping with Shocks in Mongolia Household Panel Survey.

In 2012, households that abandoned herding after the extreme winter have lower income and fewer assets (measured by the current value of all assets) compared to households that stayed in herding and compared to non-herding households that never engaged in herding (Figures 3.3 and 3.4).[13] In addition to the economic costs, abandoning herding also entails social costs for households. Herding households are held in high esteem in the society, as herding is perceived as element of true Mongolness (Murphy, 2011). Likewise, qualitative evidence suggests few households quit herding voluntarily, as this implies a loss in social status (ibid.).

3.5.2 Post-shock asset growth among households that stayed in herding

Next, we test empirically to what extent the extreme winter of 2009/10 shaped households' post-shock asset growth. If the shock significantly lowers asset

[13]If we compare the post-shock income and asset values of the households that dropped out of herding to those households that stayed in herding and had similar pre-shock livestock holdings and shock losses, the income and asset gap narrows, but remains. This seems to be driven by a higher risk of earning a very low income for former herders.

accumulation even years after its occurrence, households facing severe shock-induced livestock losses may find themselves on a different growth path compared to households experiencing few shock-induced losses. This would perpetuate shock effects, potentially trapping strongly-affected households in a low asset equilibrium. In the sample studied here, the herd size of the average herding household only reached pre-shock levels at the time of the third panel interview in 2014/15. Yet, about a quarter of the sample households had merely recovered 50 percent or less of their herd by 2014/15.

We estimate the following model of growth in herd size in the post-shock period for household i in district j at time t:

$$\begin{aligned} g_{ijt+1} = & \beta_1 dzudintensity_{ij,2010} + \beta_2 idiosyncraticshocks_{ijt} \\ & + \beta_3 herdcharacteristics_{ijt} + \beta_4 experience_{ij} + \beta_5 volatility_j \\ & + \beta_6 coping_{ij2010} + \beta_7 X_{ijt} + \eta_p + \lambda_t + \epsilon_{ijt} \end{aligned} \tag{3.6}$$

where the growth in herd size g_{ijt+1} is defined as the change in the capital stock from the beginning to the end of the year,[14] $g_{ijt+1} = k_{ijt+1}/k_{it} - 1$. Given that the panel data contain three yearly observations on herd size in the post-shock period for each household, we consider growth rates over two time periods: wave 1-2 (2012/13-2013/14) and wave 2-3 (2013/14-2014/15), 2-5 years after the shock occurred. *Dzudintensity* is measured by the number of animals a household lost in 2010 (in logs).[15]

Rejecting the null hypothesis of $\beta_1 = 0$ in favor of a negative coefficient would indicate shock persistence, i.e. the effect of the shock going beyond its immediate impact on livestock holdings in 2010.

To explore to what extent shock persistence is driven by the nature of the shock, we also control for households' exposure to $idiosyncraticshocks_{ijt}$.

[14] Recall that each panel wave was implemented over a 12-month time period, while each household was interviewed for the second and third waves exactly 12 and 24 months after the initial interview. Hence, to be more precise, the period of interest is not the calendar year, but the previous 12 months.

[15] The absolute number of animals lost, in logarithm, is used here as *dzud* intensity measure for the ease of interpreting coefficients. Specifying *dzud* intensity as proportion of the number of animals lost by the household in 2010 relative to the household's herd size in 2009 does not change the results (see column (6) of Table B.4 in the Appendix).

While such idiosyncratic shocks are unrelated to the extreme winter of 2009/10, they may still create additional consumption needs and, hence, influence asset growth. We capture exposure to idiosyncratic shocks with an indicator variable taking the value one if the household reported experiencing any idiosyncratic shock not related to livestock in the 12 months prior to each survey interview. Moreover, we account for unexpected livestock losses (due to theft, wild animals, diseases, weather conditions, and remittances given)[16] and livestock gains (due to remittances and gifts received) in the previous 12 months. Rejecting the null hypothesis of $\beta_1 = \beta_2$ in favor of $\beta_1 - \beta_2 > 0$ would indicate stronger effects on asset growth of the covariate winter disaster compared to idiosyncratic shocks.

The vector $herdcharacteristics_{ijt}$ includes various predictors for the natural growth potential of the herd at the beginning of each year. Most importantly, this includes the beginning-of-year herd size. In the theoretical framework outlined above, we show that beginning-of-year herd size may be influenced by the extreme winter of 2009/10, pre-shock herd size, as well as idiosyncratic shocks. In order to partial out the effects of those factors and allow for a separate estimation of shock and stock effects, we first regress beginning-of-year herd size on *dzud* intensity measures, 2009 herd size, and measures of idiosyncratic shocks. The predicted beginning-of-year herd size obtained from this regression is then subtracted from the observed beginning-of-year herd size. This purged beginning-of-year herd size (in logs) is then used in estimating equation 3.6. In addition, we include the share of small ruminants (sheep and goat) that have the highest natural reproduction rates among the species common in Mongolia as well as the overall share of female animals in the herd. Moreover, we control for herd size in 2009 (in logs), before the extreme weather event, which determines from which level a household starts the post-shock recovery process. Again, we account for the *volatility* in livestock numbers in the district in the past two decades, as in equation 3.5.

[16]The exclusion of losses due to livestock disease – which might be affected by the household's herding skills – does not change the results.

Similar controls for $experience_{ij}$ as in equation 3.5 are included. We additionally control for the ownership of a spring shelter that provides protection for the herd during the breeding phase. The vector $coping_{ij2010}$ represents the same set of coping strategies applied by households in 2010 – selling livestock and conducting additional nomadic movements during the *dzud* – as used in equation 3.5 above. In addition, we include the average amount of food and livestock fodder (in tons) distributed in each district per herding household, as reported by the MRCS,[17] as well as knowledge of the sub-district governor to control for the household's social network. Moreover, we explore to what extent potential transfers from other, less affected households, might have helped mitigating the adverse shock effects on asset growth. Transfers and the functioning of informal insurance arrangements likely depend on the spread of losses as well as the overall number of people affected. Therefore, we control for the within-district variability of losses (measured by the standard deviation[18]) and the share of households reporting zero livestock losses (calculated from the household panel data), as well as their interaction terms with household-level losses. These measures are calculated separately for the 2009/10 *dzud* and idiosyncratic shocks occurring during the past 12 months.

X_{ijt} stands for a vector of household and district-level controls measured in time period t. Apart from the controls used in equation 3.5, we include household size expressed in adult equivalent scales to account for the household's manpower (Deaton, 1997). As, at the district level, the available infrastructure may affect livestock marketing opportunities, we additionally account for availability of cellphone networks and the number of transportation options between the district and the province center. Finally, we include both province fixed effects (η_p) and time fixed effects (λ_t). Summary statistics of the variables used in the asset growth regression are displayed in Table 3.4.

[17] However, the distribution of emergency aid was influenced by weather-related cost and feasibility considerations and is thus not fully exogenous (see Groppo and Kraehnert, 2016). Potential effects should be interpreted as correlation only.

[18] We use district-level livestock losses from the livestock census as μ_{losses} in the calculation of the standard deviation of the within-district variance of losses. Using the within-district loss variance or coefficient of variation or basing these measures solely on loss information from our survey leaves the results unchanged.

Household specific herding skills – which may influence both beginning-of-year herd size and herd growth – are only partly observable and, thus, not fully controlled for in the model.[19] This might lead to biased estimates. Therefore, we decompose the error term into a zero mean i.i.d. part and a household-specific effect ($u_{it} = \alpha_i + \epsilon_{it}$) and estimate the model using a Hausman-Taylor panel estimator (Hausman and Taylor, 1981). This allows us to estimate the effect of time-invariant household-level variables while still controlling for unobservable household-specific herding skills. The Hausman-Taylor estimator is an instrumental variables estimator. Regressors are divided into time-varying and time-invariant as well as exogenous and endogenous variables, where endogeneity is defined as correlation with the time fixed effects. Instruments are then based on the mean of time-varying exogenous regressors (for time-invariant endogenous regressors) or values of the time-varying exogenous regressors at periods other than the current one (for time-varying endogenous regressors). This implies that we need at least as many time-varying exogenous regressors as time-invariant endogenous ones for the model to be identified. In the following, we specify all livestock-related variables (beginning-of-year and 2009 herd size, the share of female livestock, and the share of small ruminants) as endogenous.

Results (Table 3.5) show that the *dzud* has a significant effect on households' asset growth even several years after it hit the country. Households facing higher shock-induced livestock losses in 2010 have significantly lower growth rates in herd size between 2012 and 2015 compared to less-affected households (column 1). A 10 percent increase in household-level livestock losses decreases the growth rate by about 5.2 percent. Furthermore, the effects of the extreme winter on asset growth rates at the household level appear to be nonlinear, with the shock effect becoming larger in increasing losses (column 2). A 10 percent increase in losses reduces the growth rate by 4.3 percent at the 10$^{\text{th}}$ percentile of the loss distribution, but by 13.4 percent at the 90$^{\text{th}}$ percentile.

[19] Given that the panel data used in this study only cover five years and learning effects take time, we abstract from potential changes in herding skills over time.

Table 3.4: Summary statistics - Part B

Variable	Mean	Std. Dev.	Min.	Max.	N
Outcome					
Livestock growth rate	0.17	0.43	-0.96	5.91	1,710
Livestock recovery rate 2009-2014/15	1.13	0.96	0.01	20	855
Number of livestock consumed	22.20	9.05	0	68	1,710
Number of livestock sold	19.45	28.90	0	300	1,710
Number of livestock purchased	2.73	11.93	0	230	1,710
Number of newborns	78.45	61.43	0	638	1,160
Beginning-of-year herd characteristics					
Herd size	253.37	200.75	2	1613	1,710
Share of small ruminants	0.90	0.13	0	1	1,710
Share of sheep	0.38	0.19	0	1	1,710
Share of female animals	0.38	0.08	0.06	0.95	1,710
Current idiosyncratic shocks					
Experienced non-livestock related idiosyncratic shock at t-1	0.21	0.37	0	1	1,710
Unexpected livestock gains at t-1 (in percent)	0.00	0.01	0	0.67	1,710
Unexpected livestock losses at t-1 (in percent)	0.04	0.07	0	1	1,710
Beginning-of-year household characteristics					
Head and spouse are full-time herders	0.72	0.40	0	1	1,710
Household size in adult equivalents	3.81	1.11	1	8	1,710
Location is rural	0.77	0.38	0	1	1,710
Household owns spring shelter of good quality	0.21	0.35	0	1	1,193
Percent of households per district with zero LS losses	0.36	0.20	0	1	1710
Loss covariance (within-district SD)	0.03	0.03	0.00	0.22	1,710
Distance to district center (km)	25.00	19.94	0	115	1,710
Beginning-of-year district characteristics					
Availability of cellphone networks	2.46	0.78	1	4	1,710
No. of transportation options	1.34	0.61	0	3	1,710
Price index	111.14	7.70	96.72	147.61	1,710

Note: Summary statistics are reported for the pooled sample, except the livestock recovery rate. Source: Coping with Shocks in Mongolia Household Panel Survey.

Table 3.5: Annual livestock growth rates 2012-2015 (Hausman-Taylor estimator)

	Outcome: Livestock growth rates			
	(1)	(2)	(2)	(3)
Dzud intensity				
Livestock mortality in 2010 (hh) (log)[a]	-0.52***	0.57***	-0.53***	-0.70***
	(0.135)	(0.216)	(0.129)	(0.148)
Livestock mortality (log) squared		-0.17***		
		(0.032)		
Mortality covariance in 2010 (district)			0.42	
			(1.087)	
Mortality covariance*livestock mortality (hh)			-0.40	
			(1.212)	
% of HHs with zero *dzud* losses in 2010 (distr.)				0.63
				(0.952)
Zero *dzud* losses*livestock mortality (hh)				2.66***
				(0.517)
Beginning-of-year herd characteristics				
Herd size (log)[b◇]	-1.59***	-1.59***	-1.58***	-1.59***
	(0.109)	(0.109)	(0.109)	(0.109)
Share of small ruminants[◇]	-1.01	-1.01	-0.97	-1.01
	(0.768)	(0.764)	(0.772)	(0.768)
Share of female livestock[◇]	-0.09	-0.09	-0.07	-0.07
	(0.316)	(0.315)	(0.319)	(0.316)
Herd size in 2009[◇]	1.21***	1.38***	1.25***	1.33***
	(0.247)	(0.275)	(0.243)	(0.257)
Experience and gender				
Parents of head were herders	-0.09	-0.15	-0.09	-0.13
	(0.234)	(0.222)	(0.240)	(0.227)
Head always lived in current district	0.03	-0.02	0.03	0.09
	(0.145)	(0.134)	(0.145)	(0.144)
Full-time herders	0.13*	0.12	0.13	0.12
	(0.080)	(0.081)	(0.080)	(0.081)
Volatility in LS population (distr.)	0.04**	0.03*	0.04**	0.04**
	(0.018)	(0.019)	(0.018)	(0.018)
Female head	-0.21	-0.21	-0.19	-0.24
	(0.223)	(0.209)	(0.225)	(0.222)
Current idiosyncratic shocks				
Experienced idiosyncratic shock at t-1	0.00	0.00	-0.00	0.00
	(0.033)	(0.033)	(0.034)	(0.033)
Unexpected LS gains at t-1	-0.05	-0.05	-0.05	-0.06
	(0.047)	(0.046)	(0.047)	(0.047)
Unexpected LS losses at t-1[a]	-0.17***	-0.18***	-0.18***	-0.18***
	(0.017)	(0.018)	(0.017)	(0.018)
Loss covariance (district)			0.07	
			(0.698)	
Loss covariance*unexpected LS losses			0.49	
			(0.503)	
% of HHs with zero losses (distr.)				0.01
				(0.103)
Zero losses*unexpected LS losses				0.06
				(0.047)
Constant	-2.68**	-4.90***	-5.33***	-5.84***
	(1.055)	(1.285)	(1.429)	(1.538)
Household and district characteristics	YES	YES	YES	YES
Province and time FE	YES	YES	YES	YES
Observations	1,710	1,710	1,710	1,710
Number of households	855	855	855	855
P-value (Sargan-Hansen statistic)[c]	0.338	0.532	0.148	0.293

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. [◇]Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share of small ruminants. [a]In columns 3 and 4, household-level livestock mortality and unexpected livestock losses are demeaned for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. [c]P-value for the Sargan-Hansen test of overidentifying restrictions robust to arbitrary heteroskedasticity and within-group correlation. *H0*: Overidentifying restrictions are valid. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Households facing livestock losses as a result of an idiosyncratic shock during the past 12 months also exhibit significantly lower growth rates (Table 3.5, column 1). Yet, the magnitude of this effect is significantly smaller – only about one third in size – than the reduction in growth rates due to the extreme winter of 2009/10. In contrast, exposure to non-livestock related idiosyncratic shocks or unexpected gains in livestock does not significantly affect growth in herd size.

In line with our expectations, the beginning-of-year herd size has a significant and negative impact on subsequent herd growth (Table 3.5, column 1): Pastoralist households owning smaller herds in 2012 yield faster growth in herd size in the subsequent year than households owning larger herds in 2012. This result confirms the catch-up effect put forth by standard growth theory. Controlling for this catch-up effect leaves the negative effect of the extreme weather event unaltered: In a regression including an interaction term between household-level livestock losses in 2010 and beginning-of-year herd size, the coefficients of both beginning-of-year herd size and 2010 livestock losses are unchanged compared to the baseline regression (see column (2), Table B.5 in the Appendix). Neither measures of herding experience nor measures of the reproductive potential of the herd significantly affect herd growth. However, households that experienced the 2000-2002 *dzuds*, did not abandon herding afterwards and achieved full recovery until 2009 exhibit significantly higher asset growth rates also after the 2009/10 *dzud* (Table 3.6, column 5). Yet, even for this selection of households, the asset growth effect of the 2010 extreme winter remains unaltered compared to the full sample. Owning a spring shelter in a good or very good condition increases growth rates by 6 percent compared to owning a spring shelter in a poor condition or owning no spring shelter at all (column 4).

Table 3.6: Annual livestock growth rates 2012-2015 (Hausman-Taylor estimator) - Coping and emergency aid

	Outcome: Livestock growth rates				
	(1)	(2)	(3)	(4)	(5)
Dzud intensity					
Livestock mortality in 2010 (hh) (log)[a]	-0.48***	-0.44***	-0.51***	-0.47***	-0.38***
	(0.141)	(0.145)	(0.132)	(0.162)	(0.141)
Beginning-of-year herd characteristics					
Herd size (log)[b]◇	-1.58***	-1.58***	-1.59***	-1.69***	-1.51***
	(0.111)	(0.111)	(0.109)	(0.143)	(0.144)
Share of small ruminants◇	-1.07	-1.07	-1.01	-0.03	-1.71*
	(0.771)	(0.771)	(0.769)	(1.406)	(1.013)
Share of female LS◇	-0.09	-0.08	-0.09	-0.04	-0.07
	(0.320)	(0.321)	(0.316)	(0.363)	(0.415)
Herd size in 2009[c]◇	1.15***	1.11***	1.17***	1.17***	1.07***
	(0.279)	(0.276)	(0.244)	(0.313)	(0.397)
Spring shelter of good quality◇				0.06*	
				(0.037)	
Experience and gender					
Parents of head were herders	-0.12	-0.27	-0.09	-0.23	-0.19
	(0.242)	(0.389)	(0.232)	(0.442)	(0.309)
Head always lived in current district	0.09	0.25	0.04	0.03	0.09
	(0.150)	(0.303)	(0.143)	(0.186)	(0.211)
Full-time herders	0.14*	0.15*	0.13	0.23**	0.14
	(0.081)	(0.088)	(0.080)	(0.104)	(0.087)
Full recovery achieved after 2002 *dzud*					1.51***
					(0.563)
Volatility in LS population (distr.)	0.04	0.04*	0.04*	0.02	0.04
	(0.024)	(0.023)	(0.018)	(0.024)	(0.029)
Female head	-0.26	-0.24	-0.22	-0.26	-0.34
	(0.224)	(0.242)	(0.222)	(0.212)	(0.249)
Current idiosyncratic shocks					
Experienced idiosyncratic shock at t-1	0.00	0.00	0.00	-0.03	0.01
	(0.033)	(0.033)	(0.033)	(0.035)	(0.039)
Unexpected LS gains at t-1	-0.06	-0.06	-0.05	-0.07	-0.03
	(0.048)	(0.049)	(0.047)	(0.088)	(0.046)
Unexpected LS losses at t-1	-0.17***	-0.18***	-0.17***	-0.18***	-0.18***
	(0.018)	(0.018)	(0.018)	(0.021)	(0.023)
Shock coping in 2010					
Temporary migration	-0.29				
	(1.250)				
Temporary migration*LS mortality (hh)	0.12				
	(0.227)				
Livestock sold◇		2.10			
		(3.312)			
Livestock sold*LS mortality (hh)		-0.29			
		(0.762)			
Amount of aid[a]			1.05		
			(1.706)		
Amount of aid*LS mortality (hh)			-1.28		
			(1.564)		
Constant	-4.65***	-4.70***	-4.71***	-3.28*	-2.78*
	(1.547)	(1.618)	(1.499)	(1.816)	(1.531)
Household and district characteristics	YES	YES	YES	YES	YES
Province and time FE	YES	YES	YES	YES	YES
Observations	1,688	1,688	1,710	1,148	1,118
Number of households	844	844	855	574	559

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. ◇Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, share of small ruminants, whether full recovery after the 2000-2002 *dzuds* was achieved, whether the household owns a spring shelter in good quality, and livestock sold directly after the shock. The same household and district controls as in table 2 are used. [a]Household-level livestock mortality and the amount of aid received are centered for better interpretability of the interaction terms in columns 1-3. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. [c]In column 5, pre-shock livestock holdings refer to the *dzuds* of 2000-2002. Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, and MRCS emergency aid data.

Lastly, neither shock coping strategies employed by the household (Table 3.6, columns 1-2) nor emergency aid distributed in the aftermath of the shock (column 3) significantly affect post-shock growth rates. The interaction terms between shock intensity and coping strategies employed or external aid received are also not significant, implying that coping activities or aid did not mitigate the effect of the shock on subsequent growth. However, the potential for post-shock transfers in districts in which shock intensity was not uniform across households seems to play a role in mitigating the negative effect of the extreme winter on subsequent asset growth. While there is no direct effect of either shock covariance (Table 3.5, column 3) or the share of *dzud*-affected households within the district (column 4) on asset growth, the latter significantly mitigates the negative *dzud* effect. There is a significant and positive effect of the interaction between the share of households reporting zero losses during the 2009/10 *dzud* in the district and household-level losses in 2010 on post-shock growth rates. An increase in the share of households with no losses within the district by 10 percentage points decreases the *dzud* effect on subsequent asset growth by 26 percentage points. Yet, there is no such effect for losses caused by idiosyncratic shocks during the past 12 months. Hence, transfers seem to take place only after large covariate shocks and mainly from households who did not experience any losses. Taken together, we consider these findings as evidence that shock persistence is influenced both by shock severity and, for covariate shocks, the degree of covariance.

Overall, the empirical analysis shows that a one-off shock in the form of extreme weather events can have persistent effects on asset growth going beyond direct level effects, observable even five years after the shock occurred. Shock persistence is driven by both shock severity and its covariate nature. Yet, few variables apart from shock exposure and initial herd size explain the variation in growth rates across households. To better understand how households rebuild their asset base, we disentangle herd size into livestock consumption, livestock sales, livestock purchases, and natural reproduction in section 3.6.

3.5.3 Robustness tests

The empirical analysis presented here is subject to econometric challenges. More specifically, the inclusion of beginning-of-year herd size as a regressor in estimating growth in herd size – even though standard in the growth literature – might be problematic. In particular, the Hausman-Taylor estimator assumes covariates to be strictly exogenous with respect to the individual and time-specific disturbance ϵ_{it}, which also precludes feedback effects from the disturbance term to future values of the covariates. Yet, by construction, k_{it+1} is also a function of ϵ_{it}, so the strict exogeneity assumption fails. Thus, interpretation of the coefficient on the beginning-of-year herd size should be done with caution. Any potential bias introduced by this should however be small, given that the share of the total variance explained by the time-specific disturbance compared to the share explained by the individual heterogeneity is small (10 percent at most).[20] Furthermore, when re-estimating the model with a household fixed effects specification, we obtain similar coefficients on the time-varying variables (see column (3) in Table B.5 in the Appendix).

Importantly, results do not depend on the specific measure of *dzud* intensity employed. We first test the robustness of this finding by grouping households into quintiles according to the incurred losses in 2010 (the reference category being between 20 and 40 percent mortality, Table B.4, column 1 in the Appendix). Again, households in the highest loss category exhibit significantly lower growth rates than households experiencing fewer losses. Findings are also robust to controlling for district fixed effects instead of province fixed effects (column 2). This result is reassuring, given that district fixed effects control most comprehensively for variation in shock intensity across districts. Furthermore, we employ alternative *dzud* intensity measures derived from different data sources. Results are robust to measuring *dzud* intensity with district-level livestock mortality, calculated from the Mongolia Livestock Census (column 3), and to measuring shock intensity with winter temperature (column 5).

[20] In addition, we fail to reject the null hypothesis that the overidentifying restrictions are valid. This further supports the use of the Hausman-Taylor estimator in this context.

All results presented so far rely on total herd size, treating animals of different species as equal. To test for potential herd composition effects, we reestimate the model with all livestock numbers transformed in horse units. Results are very similar to the baseline findings (see Table B.2 in the Appendix), indicating that effects are not driven by differences in herd composition.

Recall that all results presented so far are derived from a sample of households with positive livestock holdings at each panel interview. To ensure the exclusion of households that abandoned herding after the 2010 extreme winter is not driving our results, we now use the compound annual asset growth rate between 2009 and each of the three panel waves instead of the observed annual growth rate. This compound growth rate n years after the shock is defined as $(k_{i2010+n}/k_{i2010})^{1/n} - 1$. It is equal to -1 for households that abandoned herding. Results (see Table B.3 in the Appendix) confirm baseline findings, regardless of whether the pre-shock herd size in 2009 or post-shock herd size in 2010 are used as baseline asset stock for the calculation of the compound annual growth rate.

As another robustness test, we define the outcome in a slightly different way – as recovery rate of a household's herd size at the time of the third panel interview (2014/15) to its pre-shock level in 2009, expressed in percent – and then test how recovery rates vary with losses incurred. Given that pre-shock herd size is directly accounted for when using the recovery rate as outcome variable, results can be regarded as a robustness test of the potentially confounding effects of differences in 2009 herd size. We regress the household-level recovery rate on intensity measures of the 2009/10 extreme winter, pre-shock herd size, as well as household, herd and district characteristics, and province fixed effects. The analysis builds on information from the third panel wave only. The cross-sectional estimation is carried out with OLS. Results are presented in Table B.6 in the Appendix. The *dzud* has a significant and negative effect on the recovery rate in herd size even five years after the extreme event, analogously to the findings in the asset growth regression. These results are robust to using district fixed effects instead of province fixed effects (column 2) and using an alternative shock intensity measure (2010 livestock mortality rate at the sub-district, column 4).[21]

3.6 Changes in herding behavior and natural reproduction

Finally, we explore potential mechanisms that might explain the observed changes in asset growth after the extreme weather event. Recall that the direction of the shock effect on household behavior remained ambiguous in the theoretical model. Do households exposed to high shock-induced livestock losses reduce off-take from their herd to stabilize their asset level? Or, on the contrary, do higher shock-losses create additional consumption needs the household seeks to satisfy by drawing down its livestock base even further? Furthermore, potentially persistent shock effects on the herd's natural reproduction rate might counteract asset preserving efforts by the household.

Analogously to the growth regression discussed above (equation 3.6), we separately regress four aspects of livestock offtake and reproduction that all matter for growth in herd size – the number of livestock consumed by the household, livestock sales, newborns, and livestock purchases – on measures of the spatial intensity of the 2009/10 extreme winter, the experience of idiosyncratic shocks, herd characteristics, herding experience, further household and district characteristics, and a price index:

$$\begin{aligned} D_{ijt+1} =& \beta_1 dzudintensity_{ij2010} + \beta_2 idiosyncraticshocks_{ijt} \\ &+ \beta_3 herdcharacteristics_{ijt} + \beta_4 experience_{ij} + \beta_5 volatility_j \\ &+ \beta_6 coping_{ij2010} + \beta_7 price_{t+1} + \beta_8 X_{ijt} + \eta_p + \lambda_t + \epsilon_{ijt}, for D = c, s, n, p \end{aligned} \tag{3.7}$$

[21] In contrast to the results for growth rates, we now find that many household and herd characteristics have a significant effect on recovery rates. We suggest that this is most likely due to the fact that unobservable herding skills and knowledge are only proxied by the covariates in this cross-sectional model, but are not directly accounted for as in the Hausman-Taylor panel estimator. All significant household and herd characteristics have the expected signs.

The number of livestock consumed c_{ijt+1}, sold s_{ijt+1}, purchased p_{ijt+1}, and the number of newborns[22] n_{ijt+1} are measured during the 12 months prior to each panel wave and are transformed into logarithm. Similar measures of the intensity of the 2009/10 winter as well as of the idiosyncratic shocks are employed as in equation 3.6 above. Beginning-of-period household, herd, and district characteristics are defined analogously to section 3.5.2. For the consumption regression, we use the share of sheep in the household's herd instead of the share of small ruminants (goats and sheep combined): While both goats and sheep play a similar role in livestock sales, sheep provide the preferred type of meat and are more important for household consumption. Furthermore, both the consumption and sales decision likely respond to food prices. Consequently, we include a price index, calculated as the average price level over the 12-months period for which livestock offtake is recorded. It is based on monthly price data from the district price questionnaire that was jointly collected with the household survey. The index is calculated as the simple average of the prices of all items contributing 2 percent or more to the consumption expenditures of an average household. Again, herding ability and experience are likely to influence households' herd management decisions, but are only partly observed. To minimize endogeneity concerns, we again employ the Hausman-Taylor panel estimator and specify all herd characteristics (beginning-of-year herd size, pre-shock herd size, share of small ruminants, and share of female livestock) as endogenous. Regressions are carried out based on data from all three panel waves.

[22]Recall that each panel wave was collected over a 12-month period. Hence, some households were interviewed before the breeding season was over and, thus, the total number of newborns is not accurately measured for these households. We therefore restrict the analyses of the natural reproduction to sample households for whom the livestock breeding season is complete at the time of the survey interview. We repeat the consumption and sales regression for this sub-sample of households and results are highly similar to the baseline regressions. This makes us confident that this sample restriction for the newborn regression does not introduce a selection bias.

Table 3.7: Livestock consumption (Hausman-Taylor estimator)

	Outcome: Number of livestock consumed by the household (log)				
	(1)	(2)	(3)	(4)	(5)
Dzud intensity					
Livestock mortality in 2010 (hh) (log)[a]	-0.15***	0.15***			-0.19***
	(0.049)	(0.051)			(0.057)
Livestock mortality (log) squared		-0.05***			
		(0.011)			
Livestock mortality in 2010 (district) (%)			-0.57***		
			(0.193)		
Winter temperature (district)				-0.24	
				(0.251)	
Winter temperature squared				-0.05	
				(0.108)	
% of HHs with zero *dzud* losses in 2010 (distr.)					0.17
					(0.327)
Zero *dzud* losses*livestock mortality (hh)					0.61***
					(0.224)
Beginning-of-year herd characteristics					
Herd size (log)[b]$^{\diamond}$	0.10	0.11*	0.10*	0.10*	0.09
	(0.062)	(0.061)	(0.061)	(0.061)	(0.060)
Share of sheep$^{\diamond}$	0.01	0.01	0.02	0.02	0.04
	(0.194)	(0.194)	(0.193)	(0.194)	(0.184)
Share of female livestock$^{\diamond}$	-0.07	-0.05	-0.07	-0.08	-0.07
	(0.223)	(0.224)	(0.222)	(0.223)	(0.222)
Herd size in 2009$^{\diamond}$	0.63***	0.63***	0.48***	0.50***	0.65***
	(0.110)	(0.114)	(0.066)	(0.069)	(0.114)
Selected beginning-of-year household and district characteristics					
Parents of head were herders	0.05	0.04	0.03	0.02	0.04
	(0.086)	(0.081)	(0.082)	(0.083)	(0.087)
Head always lived in current distr.	0.09*	0.08*	0.07	0.08	0.10**
	(0.053)	(0.049)	(0.049)	(0.053)	(0.052)
Full-time herders	0.12***	0.11***	0.11***	0.11***	0.11***
	(0.037)	(0.036)	(0.036)	(0.037)	(0.038)
Volatility in LS population (distr.)	0.00	0.00	0.00	-0.00	0.00
	(0.008)	(0.008)	(0.007)	(0.007)	(0.008)
Female head	-0.12	-0.12*	-0.14*	-0.15**	-0.13*
	(0.073)	(0.069)	(0.072)	(0.073)	(0.071)
Price index	-0.01	-0.00	-0.00	-0.01	-0.01
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Distance	0.00	0.00	0.00	0.00	0.00
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Current idiosyncratic shocks					
Experienced idiosyncratic shock at t-1	-0.04	-0.04	-0.04	-0.04	-0.04
	(0.032)	(0.032)	(0.032)	(0.033)	(0.033)
Unexpected LS gains at t-1	0.06**	0.06**	0.06**	0.06**	0.06**
	(0.026)	(0.027)	(0.026)	(0.026)	(0.026)
Unexpected LS losses at t-1[a]	0.00	0.01	0.01	0.00	-0.00
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
% of HHs with zero losses (distr.)					-0.03
					(0.110)
Zero losses*unexpected LS losses					0.04
					(0.041)
Constant	0.52	-0.21	0.74	0.42	-0.31
	(0.628)	(0.710)	(0.594)	(0.623)	(0.808)
Household and district characteristics	YES	YES	YES	YES	YES
Province and time FE	YES	YES	YES	YES	YES
Observations	1,710	1,710	1,710	1,710	1,710
Number of households	855	855	855	855	855

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. $^{\diamond}$Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share of sheep. [a]In column 5, household-level livestock mortality and unexpected livestock losses are centered for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table 3.8: Livestock sales (Hausman-Taylor estimator)

	Outcome: Number of livestock sold (log)				
	(1)	(2)	(3)	(4)	(5)
Dzud intensity					
Livestock mortality in 2010 (hh) (log)[a]	-0.55***	-0.01			-0.57***
	(0.158)	(0.159)			(0.180)
Livestock mortality (log) squared		-0.08**			
		(0.039)			
Livestock mortality in 2010 (district) (%)			-0.78		
			(0.604)		
Winter temperature (district)				-0.76	
				(0.664)	
Winter temperature squared				-0.12	
				(0.270)	
% of HHs with zero *dzud* losses (distr.)					0.73
					(0.948)
Zero *dzud* losses*livestock mortality (hh)					1.20*
					(0.623)
Beginning-of-year herd characteristics					
Herd size (log)[b]$^{\diamond}$	0.50**	0.51**	0.51**	0.50**	0.53***
	(0.207)	(0.209)	(0.206)	(0.205)	(0.204)
Share of small ruminants$^{\diamond}$	0.02	0.03	-0.01	0.04	-0.08
	(0.684)	(0.689)	(0.684)	(0.684)	(0.668)
Share of female livestock$^{\diamond}$	-0.67	-0.63	-0.69	-0.69	-0.72
	(0.571)	(0.569)	(0.573)	(0.571)	(0.570)
Herd size in 2009$^{\diamond}$	1.77***	1.81***	1.26***	1.32***	1.70***
	(0.352)	(0.380)	(0.218)	(0.225)	(0.359)
Selected beginning-of-year household and district characteristics					
Parents of head were herders	-0.22	-0.24	-0.34	-0.36	-0.19
	(0.200)	(0.214)	(0.216)	(0.219)	(0.200)
Head always lived in current distr.	0.08	0.07	0.07	0.05	0.09
	(0.125)	(0.121)	(0.123)	(0.128)	(0.122)
Full-time herders	0.11	0.10	0.09	0.06	0.11
	(0.108)	(0.106)	(0.108)	(0.110)	(0.105)
Volatility in LS population (distr.)	0.01	0.01	-0.00	-0.01	0.01
	(0.019)	(0.019)	(0.020)	(0.020)	(0.021)
Female head	0.33**	0.33**	0.25	0.22	0.30*
	(0.162)	(0.157)	(0.171)	(0.177)	(0.155)
Price index	0.01	0.01	0.01	0.01	0.01
	(0.009)	(0.009)	(0.011)	(0.011)	(0.009)
Distance	0.00	0.00	0.00*	0.00	0.00
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Current idiosyncratic shocks					
Experienced idiosyncratic shock at t-1	-0.04	-0.04	-0.05	-0.05	-0.06
	(0.079)	(0.078)	(0.075)	(0.076)	(0.079)
Unexpected LS gains at t-1	0.03	0.03	0.04	0.06	0.03
	(0.102)	(0.102)	(0.102)	(0.102)	(0.101)
Unexpected LS losses at t-1	0.09**	0.09**	0.10**	0.09**	0.11**
	(0.046)	(0.047)	(0.045)	(0.045)	(0.047)
% of HHs with zero losses (distr.)					-0.18
					(0.249)
Zero losses*unexpected LS losses					-0.31**
					(0.139)
Constant	-5.85***	-7.28***	-5.59***	-6.24***	-7.78***
	(1.664)	(2.143)	(1.737)	(1.925)	(2.218)
Household and district characteristics	YES	YES	YES	YES	YES
Province and time FE	YES	YES	YES	YES	YES
Observations	1,710	1,710	1,710	1,710	1,710
Number of households	855	855	855	855	855

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. $^{\diamond}$Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share small ruminants. [a]In column 5, household-level livestock mortality and unexpected livestock losses are centered for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Results displayed in Tables 3.7 and 3.8 show that the extreme weather event had a significant negative effect on active offtake from the herd (both livestock consumption and sales). A 10 percent increase in the losses incurred due to the *dzud* leads to a 1.5 percent reduction in livestock consumption and a 5.5 percent reduction in livestock sales (column 1). The negative relation between shock intensity and consumption as well as sales from the herd even several years after the extreme event occurred indicates that severely affected households pursue an asset conservation strategy. On the contrary, idiosyncratic shocks experienced in the past 12 months do not evoke such a strong reaction. Unexpected livestock gains lead to a small increase in livestock consumption (0.6 percent for a 10 percent increase), while there is no significant effect of unexpected losses due to idiosyncratic shocks on consumption. However, livestock sales rise in response to unexpected losses, which likely reflects the need for additional cash-income or consumption triggered by an idiosyncratic shock.

Natural reproduction, as measured by the number of newborn, is also persistently and strongly affected by the extreme winter. A 10 percent increase in shock-induced losses decreases the number of newborns by 6.9 percent (Table 3.9, column 1). This could suggest that mortality during the *dzud* was higher among female breeding stock or that this extreme event weakened animals for several years, thus impeding their reproductive capacity. Further, the effect of the extreme winter of 2009/10 is again stronger than the reduction in newborns in response to current shocks (0.3 percent for a 10 percent increase). The active asset preservation undertaken by the household in the form of reduced offtake from the herd is, thus, counteracted by the reduction in the natural reproduction of the herd even several years after the shock occurred, resulting in an overall negative net growth effect.

Table 3.9: Natural reproduction (Hausman-Taylor estimator)

	Outcome: Number of newborns (log)				
	(1)	(2)	(3)	(4)	(5)
Dzud intensity					
Livestock mortality in 2010 (hh) (log)[a]	-0.69***	0.19			-0.84***
	(0.139)	(0.186)			(0.148)
Livestock mortality (log) squared		-0.14***			
		(0.027)			
Livestock mortality in 2010 (district) (%)			-1.62**		
			(0.672)		
Winter temperature (district)				-1.51**	
				(0.736)	
Winter temperature squared				-0.56**	
				(0.277)	
% of HHs with zero *dzud* losses (distr.)					1.13
					(0.827)
Zero *dzud* losses*livestock mortality (hh)					2.03***
					(0.521)
Beginning-of-year herd characteristics					
Herd size (log)[b]◊	-0.26***	-0.26***	-0.26***	-0.26***	-0.27***
	(0.085)	(0.085)	(0.085)	(0.085)	(0.085)
Share of small ruminants◊	0.22	0.23	0.22	0.22	0.22
	(0.738)	(0.735)	(0.737)	(0.736)	(0.739)
Share of female livestock◊	-0.16	-0.15	-0.16	-0.16	-0.15
	(0.306)	(0.306)	(0.306)	(0.306)	(0.306)
Herd size in 2009◊	2.08***	2.21***	1.35***	1.41***	2.18***
	(0.247)	(0.257)	(0.137)	(0.142)	(0.246)
Selected beginning-of-year household and district characteristics					
Parents of head were herders	0.03	-0.03	-0.18	-0.17	-0.01
	(0.247)	(0.240)	(0.190)	(0.195)	(0.246)
Head always lived in current distr.	0.13	0.05	0.06	0.04	0.18
	(0.150)	(0.141)	(0.131)	(0.146)	(0.155)
Full-time herders	0.04	0.03	0.04	0.04	0.03
	(0.051)	(0.049)	(0.051)	(0.052)	(0.052)
Volatility in LS population (distr.)	0.01	0.01	0.01	-0.01	0.01
	(0.026)	(0.026)	(0.032)	(0.031)	(0.027)
Female head	-0.05	-0.10	-0.15	-0.18	-0.10
	(0.209)	(0.196)	(0.204)	(0.209)	(0.207)
Price index	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Distance	0.00	0.00	0.00	0.00	0.00
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Current idiosyncratic shocks					
Experienced idiosyncratic shock at t-1	0.01	0.01	0.01	0.01	0.01
	(0.038)	(0.039)	(0.038)	(0.038)	(0.039)
Unexpected LS gains at t-1	-0.11**	-0.11**	-0.11**	-0.11**	-0.12**
	(0.047)	(0.046)	(0.046)	(0.047)	(0.047)
Unexpected LS losses at t-1[a]	-0.03	-0.03*	-0.03	-0.03*	-0.03**
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
% of HHs with zero losses (distr.)					-0.06
					(0.158)
Zero losses*unexpected LS losses					0.07
					(0.061)
Constant	-3.89**	-5.68***	-2.21	-3.81**	-7.30***
	(1.540)	(1.720)	(1.551)	(1.749)	(1.915)
Household and district characteristics	YES	YES	YES	YES	YES
Province and time FE	YES	YES	YES	YES	YES
Observations	1,160	1,160	1,160	1,160	1,160
Number of households	580	580	580	580	580

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings and for whose livestock the breeding season is complete in all three panel waves. The same household and district controls as in table 2 are used. ◊Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share small ruminants. [a]In column (5), household-level livestock mortality and unexpected livestock losses have been centered for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table 3.10: Livestock purchases (Hausman-Taylor estimator)

	Outcome: Number of livestock purchased (log)				
	(1)	(2)	(3)	(4)	(5)
Dzud intensity					
Livestock mortality in 2010 (hh) (log)[a]	-0.21*	0.14			-0.25**
	(0.109)	(0.102)			(0.127)
Livestock mortality (log) squared		-0.06**			
		(0.024)			
Livestock mortality in 2010 (district) (%)			-0.05		
			(0.333)		
Winter temperature (district)				-0.57	
				(0.368)	
Winter temperature squared				-0.21	
				(0.130)	
% of HHs with zero *dzud* losses (distr.)					0.44
					(0.567)
Zero *dzud* losses*livestock mortality (hh)					0.94**
					(0.400)
Beginning-of-year herd characteristics					
Herd size (log)[b]◊	-0.51***	-0.51***	-0.49***	-0.50***	-0.49***
	(0.115)	(0.113)	(0.114)	(0.113)	(0.114)
Share of small ruminants◊	0.14	0.14	0.10	0.10	0.05
	(0.750)	(0.752)	(0.753)	(0.752)	(0.744)
Share of female livestock◊	0.32	0.35	0.32	0.32	0.36
	(0.505)	(0.502)	(0.507)	(0.507)	(0.500)
Herd size in 2009◊	0.47*	0.50*	0.25	0.27*	0.47*
	(0.242)	(0.260)	(0.153)	(0.158)	(0.257)
Selected beginning-of-year household and district characteristics					
Parents of head were herders	-0.33*	-0.35**	-0.37**	-0.36**	-0.33*
	(0.173)	(0.175)	(0.168)	(0.170)	(0.171)
Head always lived in current distr.	0.03	0.02	0.04	0.02	0.05
	(0.085)	(0.086)	(0.079)	(0.082)	(0.081)
Full-time herders	0.00	0.00	-0.00	-0.00	-0.00
	(0.076)	(0.076)	(0.075)	(0.076)	(0.077)
Volatility in LS population (distr.)	0.02	0.02	0.01	0.01	0.02
	(0.012)	(0.012)	(0.012)	(0.011)	(0.012)
Female head	-0.06	-0.06	-0.10	-0.10	-0.07
	(0.101)	(0.099)	(0.100)	(0.100)	(0.099)
Price index	0.00	0.00	0.00	0.00	0.00
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Distance	-0.00	-0.00	0.00	-0.00	-0.00
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Current idiosyncratic shocks					
Experienced idiosyncratic shock at t-1	0.08	0.08	0.08	0.08	0.08
	(0.065)	(0.065)	(0.062)	(0.063)	(0.064)
Unexpected LS gains at t-1	-0.04	-0.05	-0.04	-0.04	-0.05
	(0.088)	(0.086)	(0.085)	(0.086)	(0.088)
Unexpected LS losses at t-1[a]	-0.06**	-0.06**	-0.06*	-0.06*	-0.06*
	(0.031)	(0.031)	(0.031)	(0.031)	(0.035)
% of HHs with zero losses (distr.)					-0.01
					(0.152)
Zero losses*unexpected LS losses					-0.05
					(0.099)
Constant	-1.21	-2.22	-1.07	-1.43	-2.23
	(1.239)	(1.479)	(1.264)	(1.380)	(1.615)
Household and district characteristics	YES	YES	YES	YES	YES
Province and time FE	YES	YES	YES	YES	YES
Observations	1,710	1,710	1,710	1,710	1,710
Number of households	855	855	855	855	855

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. ◊Endogenous controls: Herd size (beginning-of-year and in 2009), Share of female LS, and the Share small ruminants. [a]In column 5, household-level livestock mortality and unexpected livestock losses are centered for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Lastly, we explore if households resort to purchasing livestock as a means of regulating the size of their herd. Overall, less than 20 percent of sample households purchased livestock and, even for households that do so, average livestock sales are more than twice as large as livestock purchases. As such, buying livestock does not seem to play a primary role in stimulating herd growth. Results displayed in Table 3.10 show that there is a significant negative effect of the extreme winter on livestock purchases by the household, even several years after the event occurred. A 10 percent increase in number of livestock lost at the household level due to the 2009/10 *dzud* decreases the number of livestock purchased by 2.1 percent. Yet, the magnitude of the shock effect on livestock purchases is much smaller compared to its effect on livestock sales and reproduction. When comparing the effect size of livestock losses caused by the extreme winter and by idiosyncratic shocks on purchases, we find the effect size of losses induced by the extreme winter being more than three times as large. With respect to other control variables, herding experience does not affect livestock consumption, sales, purchases, or natural reproduction. Interestingly, the distance to the next district center has no significant effect on livestock sales, suggesting that remoteness does not pose an obstacle to livestock transactions.[23] Alternatively, markets in district centers may be underdeveloped and not a relevant outlet for sales.

Finally, again there are no effects of the shock coping strategy chosen by the household, nor the amount of external emergency aid received on offtake and natural reproduction (see Table B.7 in the Appendix). On the other hand, the share of households within the district that did not experience any losses during the *dzud* significantly mitigates the negative *dzud* effect on livestock offtake and reproduction (Tables 3.7-3.10, column 5). Interestingly, there is no direct effect of the share of households experiencing no losses in 2010 on offtake. We take this as indicative evidence that the overall availability of livestock in local markets, which is expected to be lower if many households within a district experienced *dzud* losses, does not seem to be the driving factor behind the reduced livestock purchases or consumption. Put together, it seems that it is not

[23] This result also holds if distance is transformed into categorical variables, using varying thresholds.

the household's individual strategies chosen as immediate response to the extreme weather event that help the household recover, but rather the possibility of transfers from neighboring households.

To ensure that results do not depend on the specific shock measure used, we repeat all regressions with alternative measures of shock intensity (Tables 3.7-3.10). More specifically, we separately employ livestock mortality at the district (column 3) and winter temperature (column 4). All baseline findings are confirmed. Herd management decisions might also differ across households that fully rely on livestock for their livelihood and those that have alternative income sources available. Therefore, we interact household-level losses experienced in 2010 with an indicator variable that takes the value one if herding is the household's sole income source and find that the loss effect does not differ with herder status (see column (1), Table B.5 in the Appendix).

3.7 Conclusion

In this paper, we analyze to what extent a one-off extreme weather event can have persistent effects on household-level asset growth. Our focus is on an unusually harsh winter that caused massive livestock losses. The empirical context provides an interesting study setting, as the occurrence and severity of this extreme event was unanticipated by households. Furthermore, the effects of the shock are directly and immediately felt by households that primarily rely on herding for their livelihood. A regression analysis of the determinants of individual shock outcomes confirms that the immediate effects of the extreme weather event in the form of direct livestock losses are largely exogenous. The percentage of livestock lost is hardly influenced by household characteristics, post-shock coping strategies applied, or other factors under the control of the household.

Our analyses show that the extreme weather event had a significant, large, and negative effect on growth rates in herd size even several years after the shock occurred. In addition, the severity of the extreme event is a strong predictor for dropping out of the herding economy. The income and asset value of these former herders in the non-herding economy is, on average, below that of households that stayed in herding and of non-herding households that never engaged in herding, suggesting the existence of a poverty trap. Furthermore, findings indicate significantly weaker growth effects of smaller idiosyncratic shocks.

Overall, the presented results indicate that the effects of a large shock, such as the extreme weather event analyzed here, are persistent. The extreme event shapes household-level asset growth beyond immediate livestock losses. This does not necessarily imply that severely shock-affected households are trapped in poverty and will never escape (although we cannot exclude permanent effects). Growth rates are still positive for most households that continue herding in the aftermath of the extreme event, but lower compared to those households less affected by the shock. Hence, recovery takes longer. Thus, the negative effects of the shock are entrenched further into the future. Even if households try to stabilize their asset levels by reducing consumption and sales from the herd, the reproduction potential of the herd is severely impaired even several years after the shock occurred. In addition, neither coping strategies applied by the household, nor food aid and livestock fodder distributed in the aftermath of the shock significantly mitigate these persistent shock effects on asset growth at the household level. Yet, being surrounded by households that did not experience any shock losses can significantly mitigate the negative shock impact. Thus, households are generally unable to fully counteract the shock effects on asset growth rates through their own herd management behavior. Successfully rebuilding their asset base depends on transfers from other households. Overall, the detrimental effects of extreme weather events are a result of both their severity and their covariate nature.

Given the expected increase in the frequency and intensity of extreme weather events in the future, these findings have several policy implications. Shock-affected households reduce their consumption of livestock even several years after the shock occurred. This might negatively influence their food security, in particular the intake of micro-nutrients (Lehmann-Uschner and Kraehnert, 2017). As such, policies should be expanded beyond immediate disaster relief and support households throughout the long recovery process after a shock so they do not have to cut down consumption to maintain their livelihood. Furthermore, given the persistence of these shock effects, policies should also focus on strengthening households' adaptation strategies as well as help reducing households' vulnerability to these extreme events.

Chapter 4

Returns to Education among the Self-Employed: Evidence from Rural Western Uganda

Abstract

The research on the returns to education has so far focused mainly on outcomes in terms of wage income. This bypasses the reality in many developing countries in which the majority of the workforce is engaged in – mostly petty – self-employment. So far, little is known about the potential returns to education for these non-agricultural self-employed in developing countries. This paper seeks to address this gap in the literature. Using a unique sample of 1'048 market vendors in Western Uganda, I provide evidence of 7 percent returns to education even within a setting in which sectoral or occupational choices are constrained. Welch's (1970) allocative and productive efficiency gains as well as social capital increases are presented as potential mechanisms underlying the observed returns. I address endogeneity by a synthetic instrumental variable approach proposed by Lewbel (2012), additionally using the universal primary education reform. Furthermore, I find no differential returns to schooling by education level. Finally, to avoid biased estimates through confounding factors, I use the double machine learning approach proposed by Chernozhukov et al. (2018) to select additional control variables. Estimates on the returns to education are in line with the baseline specification.

JEL codes: I26, J24, O15

4.1 Introduction

Many developing countries face an employment rather than an unemployment problem (Fields, 2011): Unemployment rates are low relative to much of the developed world but there is widespread poverty among those who work. Fields finds that 85 percent of the world's poor are in working families (ibid.). One of the root causes of this phenomenon are high rates of survival-driven and thus precarious self-employment (Gindling and Newhouse, 2014; Quatraro and Vivarelli, 2014). In the absence of a market-clearing amount of adequate employment opportunities, many poor people start working on their own account (ibid.). Business performance and in turn returns from this form of necessity entrepreneurship are however lower compared to when the entrepreneur acted voluntarily (termed opportunity entrepreneurship in the literature, see f. ex. Calderon et al., 2017). At the same time, rural self-employment plays an important risk-diversifying role (Nagler and Naudé, 2014), making useful contributions to household income (Van der Sluis et al., 2005). Therefore, the question arises whether in such a static setting schooling could help the self-employed achieve higher returns. The existing literature provides tremendous evidence on the returns to education. On average, these studies find the global rate of return for one additional year of schooling to be 10 percent (Psacharopoulos and Patrinos, 2004). Yet, the vast majority of this literature is centered on industrialized countries and focuses on the returns in terms of wage income, based on the Mincerian wage regression (Card, 1999). The promise of education mainly rests on the fact that with more education, people will be able to take up better-paid jobs (see for ex. Schultz, 1988). Direct empirical evidence on the returns to education in developing countries is scarce (Peet et al., 2015). In particular, there is not much evidence on the returns to education for own-account workers when wage jobs are a rare good and the opportunities to select into different sectors constrained.

This paper addresses this gap in the literature by providing evidence on the returns to education for the self-employed in a rural developing country. The focus lies on petty vendors who act in a static environment with very limited room for entrepreneurial innovation and occupational choice. Using a sample of market vendors in Western Uganda, I find that one additional year of schooling increases average daily income from market vending by 7 percent. This is comparable to what other studies have found for settings in which selection into different types of jobs plays a much larger role. To shed light on the causal mechanisms that could explain the observed returns, I combine several strands of the existing literature and focus on three aspects of the schooling-earnings relationship: (1) the selection into the vendor type (food vs. non-food), (2) classical increases in human capital in terms of both general and business-specific skills (the worker effect in Welch's (1970) notation) and (3) social capital. I find evidence for all three mechanisms. Education increases the selection into the higher return sector, it increases the classic worker productivity through enhanced generalized knowledge as well as business specific skills and higher social capital also leads to productivity increases. In addition, financial constraints significantly hinder selection into the higher return sector. For women, education helps to alleviate theses constraints. Finally, these increases in earnings seem economically meaningful as the higher income translates into higher consumption opportunities.

Furthermore, I analyze return heterogeneity by level of education. There has been some debate as to whether returns are higher for primary schooling (see f. ex. Psacharopoulos and Patrinos, 2004) or secondary or tertiary education (Barouni and Broecke, 2014), sparking very different policy implications. Using a spline regression approach I find that within a sample of individuals following very homogenous occupational activities, returns to education do not differ by the level of education.

Finally, studies on the educational returns for entrepreneurs often fail to account for the endogeneity of education (Van der Sluis et al., 2005). I address the potential endogeneity of schooling choices and subsequent occupational outcomes by using the synthetic instruments method developed by Lewbel (2012). To avoid biased estimates due to a selective inclusion of covariates, I implement the debiased machine learning approach developed by Chernozhukov et al. (2018). Results confirm baseline findings.

So far, research on the effect of education on entrepreneurship is still disappointing, despite the large body of evidence on returns for wage employment (Van der Sluis et al., 2005). This paper contributes to the existing literature on the returns to schooling for the self-employed in developing countries in three important ways. First, this paper provides robust evidence for the existence of the returns to education in a static labour market setting with very limited options for occupational choice. It thus extends the existing literature in which returns to education are mainly discussed as sorting device between wage- and self-employment or as enabling individuals to profit from dynamic opportunities (see for ex. Vijverberg, 1986). In particular, Van der Sluis et al. (2005) shows that the more educated workers typically end up in wage employment. This effect is stronger for women and in least-developed countries where agriculture is more dominant. In contrast, the present paper finds evidence for significant returns to education among a group of own-account workers that entered self-employment mainly due to labour market push factors. This is remarkable given that the returns to education have been found to be larger for opportunity compared to necessity entrepreneurs (Fossen and Büttner, 2013).

Second, this paper enhances our understanding of where these returns even within a narrowly defined type of occupation - own-account market-vending - come from. Understanding these mechanisms is important to generalize findings from this paper to contexts other than the specific one studied here. In particular, this study shows that education is relevant for different aspects of self-employment. Schooling increases the actual labour productivity through both general education effects and enhanced business-specific knowledge. In addition, it increases earnings from non-agricultural self-employment as it raises the probability to select into a more profitable category or type of self-employment. Social network effects also improve returns.

Finally, this paper provides evidence for educational returns in an economically meaningful setting. Economic growth in Uganda, like other developing countries, has been largely jobless over the past years: the positive economic developments were not matched with increased employment opportunities. Petty self-employment is predicted to persist (Filmer and Fox, 2014) and therefore more research is needed on how skills could benefit the returns from this form of occupation.

The paper proceeds as follows: The next section discusses the theoretical foundations for analyzing the returns to education, followed by a presentation of the data and background information on educational achievements and employment opportunities in the region. Section 4.4 discusses the empirical strategy used. Section 4.5 presents the results, robustness tests are discussed in section 4.6 and section 4.7 concludes.

4.2 Theoretical Foundations

In the following, I present the theoretical foundations regarding the ways in which human capital (and thus education) affects earnings from self-employment. In particular, it is not immediately evident that education should have measurable returns in the present setting, which is static and characterized by very limited room for innovation, entrepreneurial dynamics and outside options. I therefore discuss different mechanisms that might explain the observed returns to education.

The existing literature provides different models for analyzing the returns to education. Most popular are approaches based on the human capital hypothesis (see for ex. Mincer's two seminal papers (Mincer, 1958, 1974) or Becker, 1962) which defines human capital as an investment good that helps to raise individual productivity in the future. In particular, Mincer showed the marginal effect of schooling on wages to be the result of a compensation (for the longer time spent in school), or of a simple accounting identity. Both approaches lead to similar estimation equations. While the vast majority of studies test the human capital hypothesis for wage employees, the same model has in a few studies also been applied in the estimation of the returns to self-employment (see for ex. Agrawal and Agrawal, 2019), using earnings in place of employee wages. This earnings-based approach permits however only limited insights into the channels and mechanisms leading to the observed earning increases.[1] Other studies (see for ex. Welch, 1970) have therefore followed a different approach: Based on a production function, Welch treats human capital as productive factor that not only increases the productive efficiency of a worker (the worker effect) but also the allocation of resources across sectors (the allocative effect). This allocative effect has been tested regarding the cross-sector allocation of fixed inputs (Yang and An, 2002) or of household human capital (Laszlo, 2005).

To fully capture the different mechanisms through which education might affect earnings of own-account workers, I combine the earnings and profit function based approaches to model three aspects of the education-earnings nexus. In a first step, I focus on sectoral selection, then the returns to education conditional on sectoral selection and finally the role of social networks for educational returns.

First, human capital might raise earnings by making resource allocation into different sectors more efficient (Welch, 1970; Yang and An, 2002). Adapting Welch's model on the role of education in production to the present setting of small-scale market vendors, suppose there are two products - similar to the two sectors in Welch's model - that market vendors can specialize in. The first refers to food and the second to non-food items. Given market restrictions, vendors can only select into one or the other product category, but not simultaneously in both. Gross sales Q are then

$$Q = \max[p_1 q_1, p_2 q_2] \tag{4.1}$$

with p_1 and p_2 being the sales prices (exogenous to the market vendors), q_1 and q_2 the commodities sold, which are a function of the inputs x_1 and x_2 and human capital (HC): $q_i = f(x_i, HC)$ for $i = 1, 2$. The input vector $X = (x_1, x_2)$ is the capital invested to buy one product or the other. Given the characteristics

[1]Other criticisms of the Mincer approach are voiced by Heckman et al. (2006): In particular, given the uncertainty about future earning streams and the sequentiality with which schooling decisions are taken, the rate of return estimated here should not be misinterpreted as an internal rate of return, similar to a return on other investments. Rather, it should be seen as a growth rate of market earnings with years of schooling.

of the two products, capital requirements differ between them.[2] While food can be bought in incremental amounts, units of non-food item are not infinitely separable and thus require lumpy upfront investments. Thus, the non-food sector is relatively more capital intensive than the food sector, which implies higher returns. Several studies (see for ex. Hundley, 2001; Klapper and Parker, 2010, for a review) have shown that low capital intensive industries – while requiring less upfront investments – offer lower prospective returns than the capital intensive ones, due to a lower growth and development potential.

Following Welch, the overall role of education for the earnings of market vendors can then be described by the following equation:

$$\frac{\partial Q}{\partial HC} = \left(\max\left[p_1\frac{\partial q_1}{\partial x_1}, p_2\frac{\partial q_2}{\partial x_2}\right]\right) * \frac{dx_1}{dHC} + \left(\max\left[p_1\frac{\partial q_1}{\partial HC}, p_2\frac{\partial q_2}{\partial HC}\right]\right) \tag{4.2}$$

The first term represents the marginal role of education in the selection into one or the other sector, assuming that the choice to allocate capital into one or the other sector is a function of human capital (i.e. $x_1 = x_1(HC)$). The second term refers to education's contribution to technical efficiency and will be analyzed in the second step. Utility is derived from the expected profits of the activity which are a function of capital and labour times their respective prices.[3]

In a frictionless market, entrepreneurs should be able to borrow up to their expected profits ($E(\pi_i) \equiv E(Q)$ when normalizing input prices and abstracting from additional costs). In turn, individual allocative efficiency and thus education should affect sectoral choice while individual physical capital should not. However, if financial frictions are important, sectoral allocation will also depend on individual access to financial means, as Paulson and Townsend (2004) have shown.[4] This provides me with the following testable hypothesis:

Hypothesis 1 (H1). *More education reduces selection into the low-return sector.*

[2]Capital requirements only refer to the working capital required to buy inputs as there is no other productive or manufacturing activity performed.

[3]In the absence of hired labour I will abstract from wage costs.

[4]I abstract from the fact that education could potentially affect the access to credit. To reduce endogeneity concerns, I instrument education in the robustness section.

Hypothesis 2 (H2). *Individual credit constraints are important and therefore impact sectoral choice.*

While the present analysis focuses on selection into two different product types within one specific entrepreneurial activity (market vending), the conclusions drawn from it readily extend to the general entrepreneurial selection when one sector is relatively more capital intensive.

In a second step, the returns to education for self-employment earnings are modeled conditional on the sectoral choice. This worker effect of education (Welch, 1970) is what most studies on the returns to education allude to: In a standard profit function framework, firm productivity (sometimes also termed technical efficiency) augments the returns to physical capital and labour and is itself a function of human capital. Similarly, standard human capital theory (as f.ex. in Mincer, 1958) predicts that education increases the marginal product of labour (and thus also returns).[5]

Yet, there is so far only limited evidence on the precise mechanisms through which education increases labour productivity. Regarding the returns to education for entrepreneurs, Lazear (2004) proposes a jack-of-all-trades theory: Entrepreneurs perform a multitude of tasks. Their overall performance is therefore constrained by the weakest link in their skills.[6] In turn, entrepreneurs profit more from a balanced skill set[7] than specialization. This might explain the observed returns from generalized education. In addition, there are business-specific skills – financial literacy in particular – which also contribute to greater entrepreneurial productivity (see for ex. Lusardi and Mitchell, 2014). Schooling might profit the development of these skills both explicitly if directly addressed in the curriculum or implicitly through enabling individuals to better access and process new information (Rosenzweig, 1995). To evaluate the size of the worker effect of edu-

[5] I will abstract from potential signalling gains from education as they have been found to matter primarily for wage workers but not so much for own-account workers (Van der Sluis et al., 2005).

[6] According to Lazear (2004), the income of the entrepreneur when there are two skills x_1 and x_2 is $Y_i = \lambda * \min[x_1, x_2]$.

[7] Lazear (2004) proves his model focusing on the course choice in higher education. In the setting of this paper, I transfer his idea of a weakest link to basic reading and writing skills.

cation on productivity and shed light on the mechanisms behind it, I will therefore test the following hypotheses:

Hypothesis 3 (H3). *General education increases the earnings of own-account workers.*

Hypothesis 4 (H4). *Business-specific skills (financial literacy) increase productivity of the own-account worker and are a function of her schooling.*

Hypothesis 5 (H5). *Generalized knowledge and business-specific skills are not perfect substitutes.*

In a different strand of the literature, Fafchamps and Minten (2002) as well as Kolstad and Wiig (2013) discuss the importance of social networks for entrepreneurial success. In imperfect markets in particular, social relations can help reduce transaction costs and thereby increase earnings (Berrou and Combarnous, 2011). And this increased social capital can be an additional return to schooling, as longer exposure to a social group enhances both the width as well as the strength of the social connections. This results in the last hypothesis to be tested:

Hypothesis 6 (H6). *Stronger social networks lead to increased returns for own-account workers. Schooling fosters this form of social capital.*

A final word of caution concerns the interpretation of results. In the absence of a proper control group, returns in the form of higher earnings can be attributed to individual levels of schooling (i.e. a growth rate of earnings with years of schooling, see Heckman et al. (2006) and the discussion in footnote 1) but undoubtedly establishing causality remains difficult. The following three arguments might however support a causal interpretation of the observed returns. First, the human capital hypothesis, supported for example by Card (1999), postulates that the "cognitive skills acquired in school are an important component of human capital and the return to that capital in the labour market leads in turn to higher income" (Glewwe, 2002, p.466). Second, the mechanisms presented in this section and tested empirically in section 4.5, demonstrate how this transmission of education to skills to earnings might look in practice. Third, returns to education are also observable when using an instrumented measure for education to reduce endogeneity concerns.

4.3 Background: Education and Employment in Western Uganda and Data Description

The analysis is based on a unique sample of market vendors across the entirety of 83 rural marketplaces in the seven districts of the Rwenzori Region in Western Uganda, collected in Autumn 2015. The dataset covers all relevant permanent and regular marketplaces in the region. From each marketplace, 15-20 vendors were randomly selected, resulting in a total sample of 1'048 individuals. A simple cdf-graph of market vending income by education category shows that more years of education are associated with higher income along the entire distribution (Figure 4.1). The difference manifests itself in particular for the step from no to some education. The average number of years of schooling is 5.81 and thus lower than the average at the national level, which is 10.85 for women and 11.29 for men, reflecting the rural setting of the sample. The literacy rate of 67 percent is comparable to the national average.

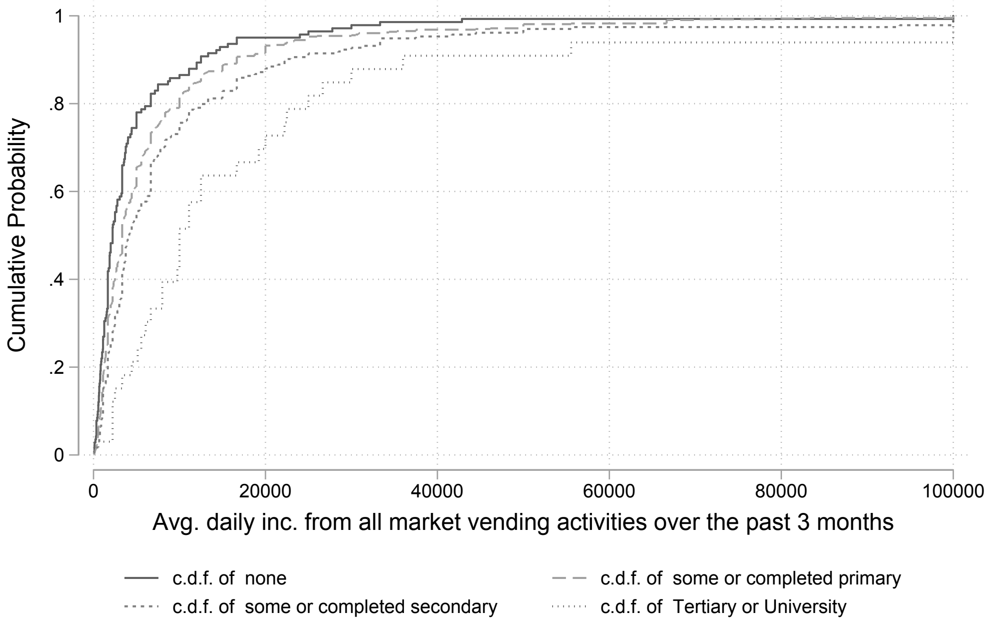
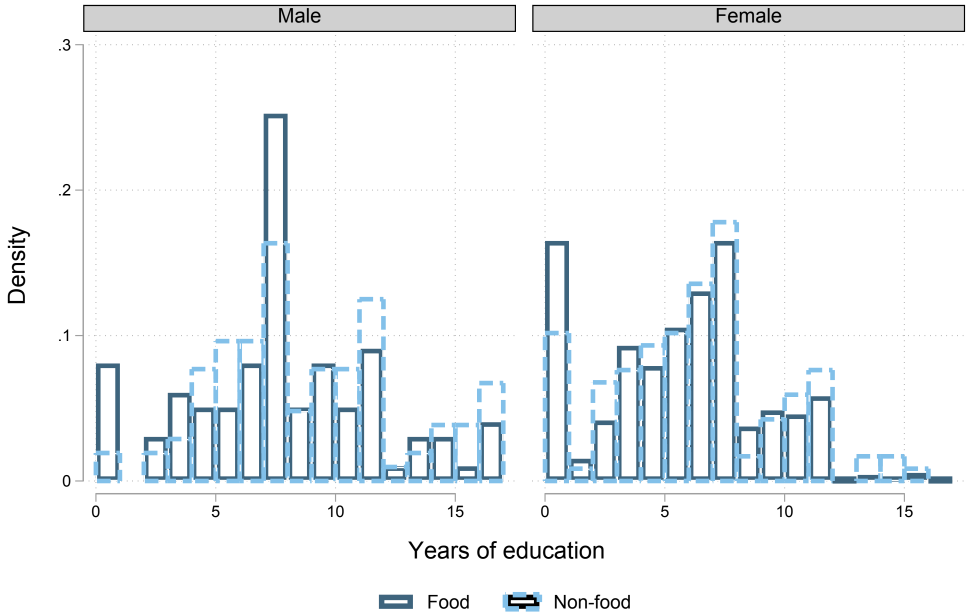


Figure 4.1: CDF for average daily market income by education category

Disaggregating education by gender and types of item sold shows three things (see Figure 4.2): Average education of women is lower than that of men. Females are more likely to have no education at all and the density mass is concentrated towards fewer years of education compared to men. Furthermore, there is a large overlap in the years of completed education between food and non-food vendors,[8] indicating there is no prerequisite level of schooling to sell a particular item. And finally, men are more likely to engage in non-food vending than women.



Note: There are 91 male food and 102 male non-food vendors. There are 694 female food and 108 female non-food vendors.

Figure 4.2: Years of education by type of item sold and gender

Summary statistics are presented in Table 4.1. The sample is predominantly comprised of women (81 percent), reflecting the fact that women are overrepresented in the services and sales sector in Uganda (Uganda Bureau of Statistics, 2018). The average age is 36 years. The market vending activities are crucial to the household's income: 70 percent of the respondents report being the main contributor to household income and market income constitutes on average 90

[8] An exception is female higher education. But note that this concerns only very few individuals in our sample.

percent of total household income. The average household respondents live in counts 6.5 people and respondents support on average 4.2 children.

Despite the sample being representative for the population of market vendors only, their employment characteristics are comparable to the average rural household in Uganda. Among our sample, only 1 percent of the respondents earned additional wage income. A high prevalence of self-employment is typical for many developing country economies, particularly in rural areas. Only one in ten smallholder households have occasional wage earning jobs (Anderson et al., 2016) with the overall self-employment rate among the active workforce in rural Uganda being 70 percent (Uganda Bureau of Statistics, 2018). Lack of a wage job is by far the most important reason for being self-employed, according to the National Labor Force Survey of the Ugandan Bureau of Statistics. Furthermore, the total median monthly income in rural Uganda is 132'000 UGX for males and 88'000 UGX for females (ibid.). This corresponds well to the median daily income from market vending activities of approximately 3'300 UGX we find in our sample.

4.4 Empirical Strategy

To estimate the role of education for the selection into selling the low-return product, I estimate the following regression using a standard probit model:

$$\begin{aligned} food_i = &\alpha_0 + \beta_1 schooling_i + \beta_2 experience_i + \beta_3 experience_i^2 + \beta_4 female_i \\ &+ \beta_5 creditconstraint_i + \beta_6 female_i * creditconstraint_i + \beta_7 X + \epsilon_i \end{aligned} \tag{4.3}$$

where the choice of covariates in the baseline specification follows the standard Mincerian wage regression model with additional controls. I measure schooling as years of completed education following standard practice in the literature.[9] More experienced vendors might be better able to observe the higher returns in the non-food sector.[10] $experience_i$ therefore measures the number of years the individual has been working as a market vendor. Similarly, the individual's gen-

[9] An exception are tertiary institutes and university, which are counted as one year each.

[10] Recall that returns in the capital-intensive industry are typically higher compared to the less capital-intensive industry, see the discussion in section 4.2.

Table 4.1: Descriptive statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Education and experience					
Years of education	5.81	3.7	0	17	1042
Able to read and write	0.67	0.47	0	1	1008
Numeracy	-0.02	0.83	-1.62	0.94	1048
Financial literacy	-0.01	0.78	-1.3	1.26	1048
Years of experience (market vending)	7.2	7.14	0	52	1030
Market vending					
Avg. daily income from market vending activities (UGX)	8092.63	14186.04	0	100000	1048
Item sold = food (fresh or cooked)	0.78	0.41	0	1	1017
Ever received fin lit training	0.23	0.42	0	1	1046
Keeps business log	0.3	0.46	0	1	1032
Business formally registered	0.25	0.43	0	1	1017
Respondent pays business taxes	0.69	0.46	0	1	1018
$>=$ one job (past 3 months)	0.21	0.40	0	1	1048
Subsistence or commercial farming	0.15	0.36	0	1	1048
Share of market income in total income	0.9	0.23	0.01	1	1046
Vending in other markets as well	0.25	0.43	0	1	916
Dist to market $>$ 30min on foot	0.15	0.36	0	1	1015
Financial constraints, wealth and social capital					
Financial constraints	0.57	0.5	0	1	1028
Total number of assets owned	46.4	27.35	0	164	943
Total current savings ('000 UGX)	416.65	1055.81	0	20000	1042
Business investments ('000 UGX, past 6 months)	413.27	788.54	0	5000	958
Relative wealth (standardized)	0	1.02	-2.13	3.78	1040
Main material of wall: burnt/unburnt bricks or cement	0.46	0.5	0	1	1035
No. of community groups	1.25	1.18	0	8	1040
Some friends are vendors	0.9	0.3	0	1	1029
Individual and household characteristics					
HH size (count)	6.5	3.97	0	34	1044
Number of children respondent supports	4.2	2.99	0	28	1036
Respondent contributes the most to HH income	0.69	0.46	0	1	1047
Age (in years)	35.94	11.77	12	78	1037
Female	0.81	0.4	0	1	1048
Risk aversion (standardized)	0.04	1.05	-1.49	2.64	1020
Patience (standardized)	0.01	1	-1.4	0.99	1038
District					
Kyegegwa	0.11	0.31	0	1	1048
Kyenjojo	0.13	0.34	0	1	1048
Kamwenge	0.12	0.33	0	1	1048
Kasese	0.11	0.31	0	1	1048
Kabarole	0.19	0.39	0	1	1048
Bundibugyo	0.29	0.46	0	1	1048
Ntoroko	0.05	0.22	0	1	1048

der might influence both push and pull factors related to the type of item sold (access to inputs or family responsibilities for example). In addition, financial constraints might play an important role in shaping entrepreneurial activity, as Paulson and Townsend (2004) have shown. The *creditconstraint* variable therefore measures whether the individual would not be able to obtain a sum of 1 Million UGX (equal to 300 USD in 2015) if they needed to.[11] In addition, household wealth - which I proxy by the standardized value of the household's total asset holdings - might affect sectoral selection for credit-constrained individuals and is therefore included as additional control. To capture heterogeneous effects of financial constraints by gender, I also interact the constraints variable with gender. Finally, the vector X_i contains additional covariates. For example, a larger household size might provide the market vendor with a larger labour force, potentially supporting the selection into the labour-intense but lower-return sector.

To ensure results do not depend on the particular measure of education employed, I categorize education into primary and secondary or tertiary education and implement a spline regression approach (see for ex. Kazianga, 2006). Furthermore, current credit constraints might be endogeneous to the stream of past realized earnings, which might bias estimated coefficients. I therefore instrument whether the individual would be able to access 1 million UGX with the household's land holdings. Land has been shown to serve as collateral for obtaining a loan (Kolstad and Wiig, 2015). And land markets are typically static in many developing countries in Africa with land titles being inherited from one generation to the next (ibid.). Land holdings are thus unlikely to respond easily to changes in household income.[12]

[11] As a robustness test, I use a more restrictive measure in which I classify all individuals as being credit constrained who are unable to access 100'000 UGX (30USD) in case of an emergency.

[12] One could however also perceive a direct effect of land holdings on the type of item sold which would render land holdings to be invalid as instrument. In particular, if own land holdings make the market vendor more likely to pursue agricultural activities and if this results in agricultural products to be sold on the market, land holdings might no longer be exogenous to the selection into the type of item sold. In a regression of vending food items on land holdings, I do however not find any significant effect. As a further robustness test, I estimate whether pursuing any agricultural activities in addition to market vending increases the likelihood to sell food items as opposed to non-food items. I find no significant effect in the full sample, but pursuing agricultural activities decreases (and not increases) the likelihood to be a food vendor for the female subsample. Alternative income could therefore also help to reduce credit constraints.

For the estimation of the returns to education in terms of productive efficiency (i.e. the worker effect) conditional on the selection into the category of item sold, I start with the Mincerian wage regression (Mincer, 1958, 1974). Despite several criticisms regarding mainly the interpretation of estimated coefficients (see for ex. Heckman et al., 2006 or Iversen et al., 2010), Mincer type specifications are still standard for estimating returns to education for both wage labourers as well as self-employed (see for example Van der Sluis et al., 2005, 2008).

$$\begin{aligned} log(earnings_i) =& \alpha_0 + \beta_1 schooling_i + \beta_2 experience_i + \beta_3 experience_i^2 + \beta_4 food \\ &+ \beta_5 female + \beta_6 X + \epsilon_i \end{aligned} \tag{4.4}$$

Entrepreneurial performance can be measured in different ways, for example as earnings, profits, survival and firm growth (for a discussion, see Van der Sluis et al., 2008). The majority of the existing literature has focused on earnings. I therefore also use the average daily market earnings as outcome variable. This is the total income from market vending activities reported for the past 3 months divided by the number of days for which the respondent reported doing these activities.[13] To correct potential reporting errors resulting in extreme values of average daily market income, I winsorize income data at the 99th percentile. Furthermore, following standard practice in the returns to education literature, I log-transform individual earnings. This eases interpretation of the estimated coefficients and allows to account for concavities or decreasing returns in the schooling-earnings relationship. Potentially heterogeneous effects of education by gender are addressed by including interaction terms.

The role of general education for increased earnings could manifest itself not only through a higher capacity to access and process new information (captured by the general measure of education, see for ex. Rosenzweig, 1995) but also through improved basic numeracy or literacy. I measure numeracy based on five questions of varying difficulty evaluating the respondent's mathematical

Put together, these findings support the claim that land holdings are linked to alleviating credit constraints but do not directly affect the choice of item sold.

[13]I thus abstract from the decision of how much to work.

ability. I then use Item Response Theory (IRT) to aggregate these measures into a reliable scale of the latent trait numeracy. Instead of summing correct responses only (see for ex. Carpena et al., 2011), the IRT approach takes a question's difficulty and discriminatory power into account (see for ex. Rasch, 1960 or Lord, 2012 for a discussion, Kaiser and Menkhoff, 2018 present an application). Following Kaiser and Menkhoff (2018), I employ the two-parameter logistic model (see for example Birnbaum, 1968), which is widely used in the construction of psychological measures. Literacy is a dummy for whether the individual is able to read and write. Furthermore, I interact the numeracy and literacy measures to investigate to what Lazear's jack-of-all-trades theory (Lazear, 2004) applies also to market vendors. In particular, a significant interaction term between reading and writing will indicate that vendors are constrained by the weakest link in their skill set.

Schooling might also help develop a better understanding of economic interrelations and skills necessary to become more productive. Financial literacy might be the most important aspect of this business-specific knowledge. I measure financial literacy based on six questions eliciting the respondent's financial knowledge, which have been widely used in the literature (see for example Lusardi and Mitchell, 2014, p.10). Similar to the construction of the latent numeracy trait discussed before, I then apply Item Response Theory to construct a measure of the market vendor's financial literacy. To account for actual financial behavior, I include savings and business investments as a robustness test. This should capture the extent to which financial knowledge already translates into good financial behavior. Savings are measured by total current savings (summed over all saving locations) and investments as total reported business investments over the past 6 months. To explore to what extent generalized education and business-specific knowledge are substitutes or complements (Schultz, 1988), I compare the estimated coefficients from a regression in which all measures have been included jointly to the estimates from regressions in which the measures have been included separately.

To evaluate the role of social networks in increased earnings from self-employment (through for example a larger pool of potential customers or access to better or more information), I additionally control in equation 4.4 for the number of community groups an individual is member of and for whether she has friends who are also market vendors.

To ensure these proposed mechanisms are indeed relevant for the observed returns to education, I estimate in separate regressions the effect of education on the selection of items sold, literacy, numeracy, financial literacy and social networks.

In addition, Iversen et al. (2010) show in the context of the Danish labour market that returns are heterogeneous and non-linear. I therefore also explore whether there are differential returns to education based on the type of school in which this additional year of education was completed, employing a spline regression approach (see for example Kazianga, 2006) and by categorizing education into completed primary, secondary and tertiary education.

A widely discussed problem in properly estimating the returns to education is endogeneity: people might select into different sectors entailing different wages for (unobservable) reasons that also affect their educational choices. In terms of this paper, individual labour productivity and thus earnings as a market vendor might be affected by unobservable characteristics such as grit, ability or motivation that also influence the schooling decision. This paper addresses endogeneity concerns in two ways. First, I analyze returns to education within a homogenous sample, enabling me to abstract from concerns relating to occupational or sectoral choice. Second, I use an instrumental variable regression approach that relies on synthetic instruments as developed by Lewbel (2012). In addition to the heteroskedasticity-based instruments this estimator constructs from within the system, this approach allows for additional external instruments. I am therefore also using Uganda's universal primary education reform from 1996 as additional instrument.

Finally, there might be other factors affecting self-employment outcomes. Omitting these aspects from the analysis might lead to biased estimates, in particular if these factors are linked to educational outcomes. I therefore pay particular attention to accounting for potential confounders to be included into the control vector X. Existing research on the determinants of entrepreneurship selection and performance for example shows that self-employment outcomes are a function of risk attitude, access to capital, labor market experience, business acumen, family background, psychological traits and education (see for ex. Le, 1999; Van der Sluis et al., 2008, both focusing on developed economies though). First, I include two measures of personality traits (risk aversion and patience) in the analysis. Patience is measured by the standardized z-score of the answers to the question how willing respondents would be take a 30 minute walk instead of taking a taxi for that move (4-point scale). And risk attitudes are measured by the standardized z-score of a widely used non-incentivized survey item asking for the participant's willingness to take risks on a 0 to 10 scale (see Dohmen et al., 2011). Second, I use the debiased (or double) machine learning approach proposed by Chernozhukov et al. (2018) to select additional confounders. This method partials out the effects of additional x's from the estimator of interest (education). To best reduce the impact of covariate selection on the estimated education effect, this approach uses the least absolute shrinkage or selection operator (LASSSO) for covariate selection in both the regression of market income as well as of education on the control variables. In a next step, it applies sample splitting as well as cross-validation to the partialling-out estimator.[14]

4.5 Results

4.5.1 Allocative efficiency - Selection into type of item sold

The first part of the analysis focuses on the role of human capital for increasing the allocative efficiency of individual market vendors. Results from the estimation of equation 4.3 with a probit regression controlling for district fixed

[14]For example, to control for a potential "necessity" channel according to which respondents with a larger dependency share in the household need to earn more, I include household size, whether the respondent is the main contributor to household income and the number of children supported by the respondent. In addition, a "formalization" dividend could also affect market vending income. I therefore also include whether the respondent pays business taxes as covariate. And additional income sources such as farming might be linked to the choice of item sold and could affect earnings. Farming is therefore also included as covariate. The full list of covariates included in the LASSO estimation as well as in the partialling-out is presented in the appendix.

effects and with standard errors clustered at the market level show that education indeed significantly affects the choice of item sold (Table 4.2). In particular, schooling is associated with less selection into the labour-intensive but lower return sector. With each additional year of schooling, the likelihood of selling food instead of non-food products declines by 1 percentage point (column 1). Results from a regression that uses education categories instead of continuous years shows a similar picture: Individuals who have attended primary school are 8 percentage points less likely to be food vendors, for those with secondary or higher education, the probability of vending food decreases by 11 percentage points (column 4).[15]

In addition to human capital, there is an important gender dimension to the sectoral allocation. Women are 25 percentage points more likely to be active in the lower-return segment of food vending instead of the higher-return non-food vending. The efficiency-enhancing effect of education seems however not to differ between the sexes: Interaction terms between the education and the gender of the market vendor remain insignificant (Table 4.2, columns 3 and 5). Several reasons for these gender differences in allocative efficiency are conceivable. While the data do not allow to test for the potential existence of norms or taste-based selection into food vending, financial constraints are expected to affect the choice of item sold and are likely to differ by gender. As discussed in the theoretical foundations before, vending non-food items yields higher returns but also requires larger upfront investments. Being unable to obtain a credit therefore constitutes a significant barrier to selecting into selling this type of item. And the risk of being credit constrained is 61 percent for a women and thus 1.5 times higher than for a men. In a next step, I therefore also control for reported financial constraints of the individual (Table 4.2, column 2). Indeed, facing credit constraints makes individuals 6 percentage points more likely to enter the low-return item category. When interacting gender with credit constraints (Table 4.2, column 5), I find that this result is primarily driven by female market vendors.

To further explore the extent to which human capital and financial constraints

[15] Note that education patterns between food and non-food vendors are very similar (see Figure 4.2).

Table 4.2: Selection into type of item sold - Baseline specification

	Outcome: Type of item sold = food				
	(1)	(2)	(3)	(4)	(5)
Years of education	-0.01***	-0.01**	-0.01*		
	(0.003)	(0.004)	(0.005)		
Highest educ level: Some or completed primary				-0.08**	-0.14
				(0.034)	(0.096)
Highest educ level: >= secondary				-0.11**	-0.20*
				(0.043)	(0.103)
female	0.26***	0.25***	0.22***	0.25***	0.17*
	(0.027)	(0.026)	(0.059)	(0.026)	(0.098)
educ yrs.*female			0.00		
			(0.007)		
Primary educ*female					0.07
					(0.106)
Sec or tert educ*female					0.12
					(0.112)
Years of experience (market vending)	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Experience squared	0.00	0.00	0.00	0.00	0.00
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Credit constraints		0.06*	0.05	0.06**	0.05
		(0.030)	(0.057)	(0.030)	(0.056)
Credit constraints*female			0.02		0.01
			(0.058)		(0.058)
HH size		0.00	0.00	0.00	0.00
		(0.003)	(0.003)	(0.003)	(0.003)
Observations	995	972	972	972	978
Credit constr. for females			0.06**		0.06***
			(0.030)		(0.030)
Yrs. of primary educ for females					-0.07*
					(0.044)
Yrs. of sec. or tert. educ for females					-0.08
					(0.053)
Educ for females			-0.01		
			(0.005)		

Table reports marginal effects. Standard errors (clustered at the market level) in parentheses; District FE included; *** p<0.01, ** p<0.05, * p<0.1

affect the individual's allocative efficiency, I include a triple interaction between gender, credit constraints and education into the estimation of the sectoral allocation. Predictive margins at different combinations of the vendor's gender, schooling and reported credit constraints are presented in Figure 4.3. Results suggest a double role of education: First, confirming baseline findings, education reduces the selection into vending the low-return product type and there-

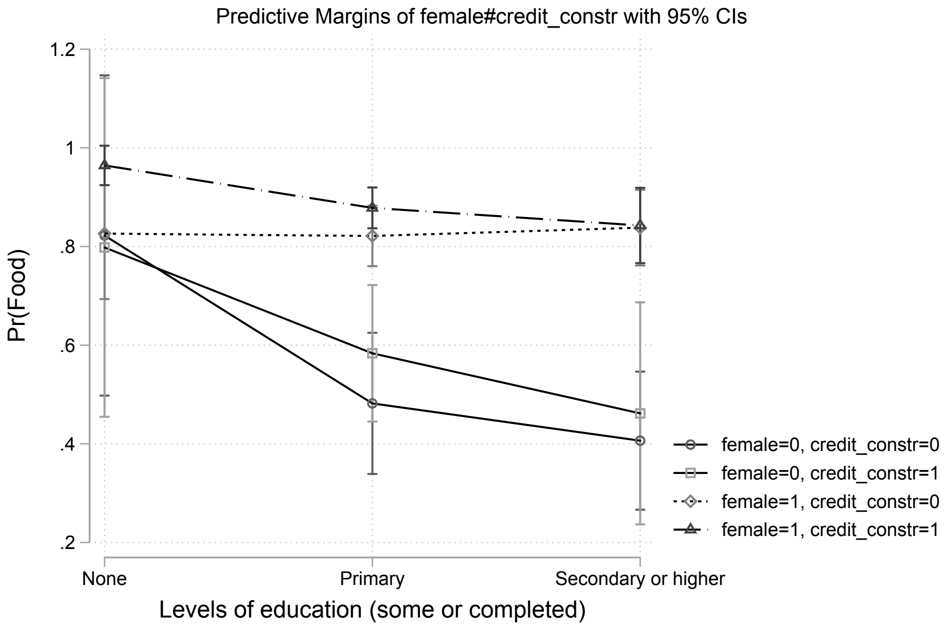


Figure 4.3: Predicted probabilities for selecting into the low-return vending activity at different levels of gender, education and credit constraints

fore increases the allocative efficiency of the market vendor. Second, for women a higher level of education seems to alleviate the constraining role played by a restricted access to credit. Women without education have a predictive margin of 0.96 to be a food vendor as opposed to vending non-food items when they are credit-constrained whereas those who do not face credit constraints have a predictive margin of 0.83. At secondary or higher education, the predictive margin to be a food vendor for credit-constrained women drops to 0.84 whereas those of the non-credit-constrained women remains unaffected. It is important to note however that the interaction terms are only significant in the regression for the female subsample (see Table 4.3, column 4) but not in the full sample. I therefore present these results only as suggestive evidence of the double role of education. More research is needed in this respect.

Table 4.3 presents robustness tests. First, I use individual land holdings as instrument for financial constraints to address a potential endogeneity of reported credit constraints to previous income streams (Table 4.3, column 1). To account for the fact that credit constraints matter primarily for females, this regression is estimated for the female subsample only. Furthermore, I additionally control for household wealth - proxied by the standardized value for the total number of assets owned by the household - to fully capture the effect of access to financial means (column 2 and 3). Results confirm the baseline finding that financial constraints diminish selection into the higher-return non-food vending activities.

Overall, the data provide support for hypotheses 1 and 2: Human capital increases the allocative efficiency of market vendors. Individuals with a higher level of education are more likely to invest into vending the higher-return non-food products instead of the lower return food products. This might be driven by enhanced capacities to access and process new information (Rosenzweig, 1995). At the same time, financial constraints restrict selection into the high-return sector, but this restricting effect loses importance with higher levels of education.

4.5.2 Returns to education conditional on sectoral selection (worker effect) - Baseline specification

Results provide evidence for significant returns to education: One year of additional completed education is associated with increases in average daily income of 7 percent in the baseline regression (Table 4.4). This is comparable to the global average rate of return for wage employees (Psacharopoulos and Patrinos, 2004; Ashenfelter et al., 1999) but slightly lower than educational returns found for developing economies – in particular Sub-Saharan African countries – where average rates of return are closer to 12 percent per year (ibid.). A comparison with results from the entrepreneurship literature shows that these baseline returns are in line with those found for opportunity entrepreneurs in a developed economy (Fossen and Büttner, 2013). They are larger by 2 percentage points for average returns to entrepreneurs found in a meta-study for developed economies (Van der Sluis et al., 2008) and larger by 3 percentage points than those found for necessity entrepreneurs (Fossen and Büttner, 2013).

An additional year of experience as vendor on the market increases income by 4 percent. Additionally controlling for age (results not shown) leaves results unaffected: The coefficient on age is very close to zero and insignificant and point estimates for experience and schooling are not significantly different from the baseline specification. Furthermore, average daily income is substantially lower for women compared to men (by 46 percent).[16] In line with other studies that provide evidence for higher returns to education for women than men (Van der Sluis et al., 2008), I find that the returns to primary and secondary education in the spline regression specification accrue to females only (Table 4.4 columns 3 and 5).[17] The type of item sold significantly affects income from vending activities, as already discussed in the theoretical foundations section. Compared to non-food vendors, the income of food vendors is 41 percent lower (Table 4.4, column 1). Part of this effect stems from the gender differences in sectoral selection: When additionally controlling for the vendor's sex, the effect of the item choice on income drops to 24 percent (Table 4.4, column 2).

In the present setting, the returns to one additional year of completed education do not differ between primary, secondary and tertiary education. In a spline regression following Kazianga (2006), point estimates for the effect of an additional year of schooling on income do not differ significantly between different education levels (Table 4.4, column 3).[18] This has two implications. First, even for occupations such as market vending that do not seem very skill intensive, pursuing schooling up to secondary or higher education has positive returns.[19] Second, the differences in returns by levels of education found for example by Psacharopoulos and Patrinos (2004) and Barouni and Broecke (2014) might be context specific, depending on the schooling system or earning environment considered.

[16] I hypothesize this could be driven by the lower number of hours worked per day by women due to family obligations. Unfortunately, the data at hand do not allow to test this hypothesis.

[17] Yet, when using the continuous education measure, the education-income nexus is unaffected by gender, as can be seen by the insignificant interaction terms between gender and schooling (Table 4.4 column 4).

[18] Using an alternative spline regression specification $(educyears + (educyears - 7) * I(educyears \geq 7) + (educyears - 13) * I(educyears \geq 13))$ as shown in Greene (2000, p.322), I fail to reject the null hypothesis that the slope of the function is constant (i.e. the coefficients on additional years of secondary and on tertiary education are jointly zero).

[19] Note that positive returns to additional years of schooling in secondary or higher education are also observable among the subsample of food vendors only.

4.5.3 Generalized education vs. business-specific skills

The next section explores the mechanisms behind the observed productivity increasing effect of education once sectoral choice is accounted for. First, the productivity of the market vendor might grow due to enhanced business-specific skills as a result of more education. For market vendors, such knowledge salient to good business practice could be financial literacy. As expected, I find that financial literacy is associated with increases in income (Table 4.5, column 1). A one standard-deviation increase in financial literacy can be attributed to an income increase of 18 percent. To evaluate whether business-specific knowledge translates into "good financial behaviour", I use business investments and total savings as proxy for business-specific knowledge as a robustness test (Table 4.8, column 3). Again, baseline results are confirmed. A 10 percent increase in business investments is associated with a 1.1 percent higher income from market vending activities and increasing total savings by 10 percent with an income increase of 0.3 percent.[20] The point estimate for the effect of education reduces in size but still remains significant.

Second, the generalized knowledge obtained through schooling also seems to profit the self-employed as it improves their capacity to access and process new information (Rosenzweig, 1995). This generalized knowledge could be measured as the residual returns to education once business-specific knowledge is accounted for. Indeed, the dividend to this general knowledge seems to materialize in addition to the returns on business-specific knowledge (financial literacy). The point estimate for years of schooling reduces only by 1 percentage point when a measure of financial literacy is included (Table 4.5, columns 1 and 5). In the reasoning of Schultz (1988), generalized knowledge is therefore not a perfect substitute for the business-specific skills.

One could think of an alternative explanation for the relative stability of the education coefficient even when a measure of (financial) ability is included. In a wage employment setting, this finding would provide support for the sorting hypothesis: Firms choose their workers based on observables (their education level) and not unobservables (their ability) (see Weiss, 1995). In self-employment

[20]As there are other factors potentially influencing business investments and savings, I am cautious to not claim a causal relationship here.

however, income and productivity are much closer linked and sorting or sheepskin effects should play a much smaller role (see Glewwe, 2002). I therefore use numeracy and literacy as more specific measures of generalized knowledge (Table 4.5, column 3-5). While the level effects of numeracy and literacy are not significant when included in addition to the general schooling measure[21] (Table 4.5, column 3), the interaction term between numeracy and literacy is significant. This suggests basic skills (such as numeracy and literacy) are not conducive to increased earnings when only one of them is present. This becomes even more apparent when numeracy and literacy are used as proxy for generalized education and are thus included instead of the education measure (and not in addition to it, Table 4.5 column 4 and 5). For very low levels of numeracy, I do not find any significant effect of being able to read and write on market income. Yet, once numeracy gets large enough (i.e. once a market vendor has a numeracy level above the 25th percentile), literacy significantly increases earnings. And this effect gets larger with increasing numeracy: At a numeracy level above the 75th percentile, literacy leads to income increases of 45 percent. The same holds true for numeracy. While there is no significant income effect of numeracy for those unable to read and write, a one standard-deviation increase in numeracy increases income for the literate by 12 percent. Additionally controlling for business-specific skills in the form of financial literacy does not alter the results (Table 4.5, column 5).

Both generalized knowledge as well as business-specific skills lead to an increased income of market vendors, which shows that the two measures pick up different aspects of the education-earnings nexus. This provides supportive evidence for Lazear's jack-of-all-trades theory (Lazear, 2004): Market vendors perform a multitude of tasks and therefore profit from a balanced skill set. As evidenced by the positive and significant interaction term between literacy and numeracy, a skill will only deploy its true potential when the self-employed disposes of complementing skills at a matching level.

[21] Note however that the effect of years of education remains highly significant in this regression. This suggests, the effect of schooling encompasses more than the acquisition of basic numeracy and literacy skills.

4.5.4 Social capital

Finally, productivity increases might accrue due to an enlarged social network. The social network, as measured by the number of community groups an individual is a member of, is associated with significant increases in income (Table 4.5, columns 6 and 7). Being active in one community group leads the market vendor to receive an income higher by 28 percent compared to those not engaged in any community groups and the income rise amounts to 72 percent if the market vendor is active in more than three community groups. Intuitively, a larger social network could improve the market vendor's access to information or enlarge the vendor's client base. In addition, the effect of social capital does not differ by the achieved education level. Interaction terms between years of schooling and community group activities remain insignificant (Table 4.5, column 7). Furthermore, the network effect does not seem to work through knowing more people on the market: whether or not any friends or relatives are market vendors as well has no effect on income (Table 4.5, column 8).

Overall, results provide evidence for hypotheses 3 - 6. Both generalized knowledge and business-specific skills increase productivity of the self-employed and thus lead to higher income once selection into the type of item sold is accounted for. In addition, enhanced social capital also leads to increases in income for the self-employed. To what extent literacy, numeracy, financial literacy as well as community group engagement are causally linked to schooling is explored further down in section 4.6.1 (instrumenting education).

Furthermore, the different skill sets are not perfect substitutes for each other. When controlling for business-specific knowledge or the vendor's social capital, the point estimate on the years of schooling reduces by 1 to 2 percentage points but still remains highly significant. The resulting returns to education are still comparable to the average returns for entrepreneurs found by Van der Sluis et al. (2008). This provides further supportive evidence for the role of education in enhancing individual generalized knowledge, when defined as this residual return to schooling once other mechanisms are accounted for. Improving individual capacities to access and process new information (Rosenzweig, 1995) might lead to productivity increases for example through better procurement strategies, improved (business) planning or different (more successful) vending strategies. Given the type of market vending activities analyzed, business investments as discussed in the literature on entrepreneurial returns to education are not widely applicable in the setting of this study.

Finally, my findings suggest that even in a setting in which formal wage earning jobs are a rare good, there are returns to education that are in line with results found for environments that allow for selection. Yet, the exact magnitude of returns, in particular also at different educational levels, might depend on specific circumstances and the type of self-employment. For example, large business owners who also employ workers are expected to profit more from tertiary education.

4.6 Robustness Tests

The estimated positive returns to education do not depend on the specific measure of education used. Returns to education are robust to measuring education in an alternative way (categorize education into primary, secondary and tertiary education). Estimated effects are in line with the number of years per primary and secondary education. Note that it does not make a difference whether the individual just completed some or all years of primary or secondary education. In a separate regression (results not shown), in which some primary/secondary and completed primary/secondary education are defined as separate categories, there is no statistically significant difference between the coefficients on some and completed education of one school type. Returns to education are also unaffected by previous financial literacy trainings, even if having received financial literacy training increases income by 30 percent.

4.6.1 Instrumenting education

Endogeneity of education is mostly discussed in terms of an ability bias (although Ashenfelter et al. 1999 find it to be small). In our sample, the socioeconomic situation of the respondent's parents might have a significant impact on schooling decisions of the individual and occupational outcomes in terms of the financial means disposable for investment as well as the choice of item sold. The parental socioeconomic background is however unobservable here. To make sure endogeneity is not the driver of the results, I employ a novel approach to estimating endogenous regressor models proposed by Lewbel (2012). This method takes the form of a modified 2sls estimator that uses heteroscedasticity in the errors of a linear projection of the endogeneous variable on all other regressors (like the first stage in a traditional IV approach).[22] Identification then stems from having some regressors that are uncorrelated with the product of these heteroskedastic errors. In addition, the approach also allows for the inclusion of external instruments to improve efficiency. I use Uganda's universal primary education reform from 1996. Specifically, the additional instrument used is whether the individual could have profited from at least one year of free primary education under the UPE reform. Results show that the positive effect of education on income remains under instrumentation and is thus not driven by unobserved factors (Table 4.8 column 5).

[22]The chi-squared test statistic for this linear projection in our baseline model is 160.79 (or 316.51 when cluster fixed effects are included). I thus reject the null of constant error variance.

Table 4.3: Selection into type of item sold - Robustness tests

	Outcome: Type of item sold = food			
	(1)	(2)	(3)	(4)
	IV			
Years of education	-0.00	-0.01*	-0.01*	
	(0.004)	(0.004)	(0.005)	
Highest educ level: Some/completed primary				-0.00
				(0.055)
Highest educ level: >= secondary				0.02
				(0.061)
Female		0.23***	0.19***	
		(0.026)	(0.054)	
Educ yrs.*female			0.01	
			(0.007)	
Years of experience (market vending)	-0.00	-0.00	-0.00	-0.00
	(0.005)	(0.004)	(0.004)	(0.004)
Experience squared	0.00	0.00	0.00	0.00
	(0.000)	(0.000)	(0.000)	(0.000)
Credit constraints	0.05*	0.05*	0.05*	0.16**
	(0.027)	(0.030)	(0.030)	(0.078)
Primary educ*credit constraints				-0.11
				(0.076)
Secondary educ*credit constraints				-0.16*
				(0.086)
Total no. of assets owned (std.)		-0.03*	-0.01	
		(0.013)	(0.022)	
Assets*female			-0.03	
			(0.025)	
HH size	0.00	0.00	0.00	0.00
	(0.004)	(0.003)	(0.003)	(0.004)
Assetholdings for females			-0.04**	
SE			(0.015)	
Educ for females			-0.00	
SE			(0.004)	
Observations	775	877	877	790

Table reports marginal effects. Standard errors (clustered at the market level) in parentheses; District FE included; *** $p<0.01$, ** $p<0.05$, * $p<0.1$
In columns 1 and 5, the model has been estimated for the subsample of female market vendors only. In column 1, credit constraints have been instrumented with access to land; standard errors for this regression are obtained through bootstrapping with 50 replications

Table 4.4: Returns to education: Worker effect - Generalized knowledge

	Average daily income (log)				
	(1)	(2)	(3)	(4)	(5)
Years of education	0.07***	0.06***		0.06***	
	(0.009)	(0.010)		(0.019)	
Yrs of primary educ			0.05***		0.01
			(0.017)		(0.045)
Yrs of secondary educ			0.05***		0.02
			(0.011)		(0.025)
Yrs of tertiary educ			0.07***		0.06***
			(0.015)		(0.021)
female		-0.47***	-0.46***	-0.46**	-0.70***
		(0.102)	(0.100)	(0.185)	(0.257)
Years of experience	0.04***	0.04***	0.04***	0.04***	0.04***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Experience squared	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Item sold = food	-0.41***	-0.26***	-0.26***	-0.26***	-0.26***
	(0.097)	(0.086)	(0.086)	(0.087)	(0.087)
Female*primary years					0.04
					(0.048)
Female*secondary years					0.03
					(0.028)
Female*tertiary years					0.01
					(0.027)
Female*education (years)				-0.00	
				(0.022)	
Constant	7.99***	8.35***	8.38***	8.34***	8.60***
	(0.177)	(0.185)	(0.200)	(0.223)	(0.307)
Observations	995	995	995	995	995
R-squared	0.087	0.104	0.105	0.104	0.106
Yrs of primary educ & female = 1					0.05***
					(0.018)
Yrs of secondary educ & female = 1					0.05***
					(0.013)
Yrs of tert educ & female = 1					0.06***
					(0.020)
Educ (years) & female = 1				0.06***	
				(0.011)	
Primary - secondary educ (years)			-0.00		
			(0.014)		
Secondary - tertiary educ (years)			-0.02		
			(0.017)		

Standard errors (clustered at the market level) in parentheses; District FE included; *** p<0.01, ** p<0.05, * p<0.1

Table 4.5: Returns to education: Worker effect - Business specific knowledge

	Average daily income (log)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Years of education	0.05***	0.05***	0.05***			0.05***	0.06***	0.06***
	(0.010)	(0.010)	(0.013)			(0.010)	(0.018)	(0.010)
Literacy			0.05	0.27***	0.24***			
			(0.101)	(0.085)	(0.085)			
Numeracy			-0.08	-0.08	-0.12			
			(0.074)	(0.076)	(0.077)			
Literacy*Numeracy			0.17**	0.19**	0.19**			
			(0.086)	(0.086)	(0.086)			
Years of experience	0.04***	0.04***	0.04***	0.04***	0.04***	0.03**	0.03**	0.04***
	(0.014)	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Experience squared	-0.00	-0.00	-0.00*	-0.00*	-0.00	-0.00	-0.00	-0.00
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Item sold = food	-0.26***	-0.26***	-0.28***	-0.30***	-0.29***	-0.28***	-0.28***	-0.26***
	(0.088)	(0.088)	(0.091)	(0.091)	(0.091)	(0.087)	(0.088)	(0.087)
Female	-0.44***	-0.44***	-0.43***	-0.51***	-0.48***	-0.43***	-0.43***	-0.47***
	(0.103)	(0.103)	(0.105)	(0.108)	(0.109)	(0.108)	(0.108)	(0.100)
Financial literacy	0.18***	0.15*			0.18***			
	(0.051)	(0.088)			(0.057)			
Education*financial literacy		0.00						
		(0.013)						
# of community groups: 1						0.28***	0.27***	
						(0.086)	(0.087)	
# of community groups: 2						0.56***	0.55***	
						(0.100)	(0.101)	
# of community groups: >= 3						0.72***	0.72***	
						(0.123)	(0.127)	
Community group(1)*Educ							-0.01	
							(0.025)	
Community groups(2)*Educ							-0.02	
							(0.027)	
Community groups(>= 3)*Educ							-0.01	
							(0.036)	
Some friends are vendors								-0.06
								(0.132)
Constant	8.37***	8.37***	8.31***	8.51***	8.51***	8.12***	8.07***	8.38***
	(0.192)	(0.192)	(0.203)	(0.213)	(0.219)	(0.196)	(0.218)	(0.224)
Observations	995	995	959	964	964	988	988	990
R-squared	0.115	0.115	0.105	0.091	0.102	0.142	0.142	0.105

Standard errors (clustered at the market level) in parentheses; District FE included; *** p<0.01, ** p<0.05, * p<0.1

Table 4.6: Returns to education: Worker effect - Robustness tests (causality)

	Fin Lit	Fin Lit IV Reg	Numeracy	Numeracy IV Reg	Literacy	Literacy IV Reg	Com. Groups	Com. Groups IV Reg
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Years of education	0.04***		0.05***		0.07***		0.05***	
	(0.008)		(0.006)		(0.004)		(0.012)	
Years of experience (market vending)	0.01	0.00	0.03***	0.03***	0.00	-0.01***	0.06***	0.06***
	(0.008)	(0.006)	(0.011)	(0.010)	(0.004)	(0.004)	(0.013)	(0.012)
Experience squared	-0.00	-0.00*	-0.00**	-0.00***	0.00	0.00	-0.00***	-0.00***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
female	-0.17**	-0.24***	-0.19***	-0.29***	-0.05*	-0.18***	-0.22**	-0.34***
	(0.073)	(0.064)	(0.069)	(0.066)	(0.029)	(0.030)	(0.110)	(0.103)
Item sold = food	-0.03	-0.05	0.03	-0.01	-0.02	-0.07**	0.13	0.09
	(0.066)	(0.060)	(0.062)	(0.056)	(0.030)	(0.031)	(0.101)	(0.094)
At least 1 yr. of completed education		0.43***		0.44***		0.50***		0.21
		(0.134)		(0.133)		(0.068)		(0.166)
Constant	-0.14	-0.28*	-0.31**	-0.27	0.39***	0.54***	0.76***	0.99***
	(0.134)	(0.153)	(0.126)	(0.168)	(0.058)	(0.083)	(0.217)	(0.256)
Observations	995	991	995	991	959	954	988	984
R-squared	0.072	0.063	0.113	0.080	0.379	0.297	0.091	0.078
Hansen J stat		9.382		10.67		21.27		16.70
Hansen p-value		0.496		0.384		0.0193		0.0812

Standard errors (clustered at the market level) in parentheses; District FE included; *** p<0.01, ** p<0.05, * p<0.1

IV-regressions estimated using Lewbel's (2012) method with Uganda's Primary Education reform as additional instrument.

To further substantiate whether the proposed mechanisms are indeed linked to education, I estimate a basic first stage for the effect of education on financial literacy, literacy, numeracy and participation in community groups (Table 4.6). The association between years of schooling and these mechanisms points in the expected direction: Higher levels of education are associated with higher levels of business specific-knowledge, generalized knowledge and social capital. Given the potential endogeneity of education not only to unobserved individual skills and talent but also to parental socioeconomic background, I use again an instrumented measure of education to be able to establish a causal relationship (see Lewbel, 2012). The point estimates of instrumented education on the different mechanisms still point in the right direction and are significant for business specific knowledge (financial literacy), numeracy and literacy, but not social capital. However, I reject the null hypothesis of joint instrument validity in the regression for literacy and community group engagement. Conclusions on the effect of schooling on the market vendor's literacy and social capital are therefore less straightforward to establish: The insignificance of instrumented education (or potentially invalid instruments) might be indicative of the fact that social capital and literacy are relevant for earning outcomes in their own right but are not a transmission belt from education to earnings. At the same time, I cannot reject the hypotheses that the instruments only pick up variation in education that is irrelevant for the channels' effect on earnings.

4.6.2 Confounders

Confounding factors – particularly if they are linked to both education as well as productivity outcomes – might lead to biased estimates. I am therefore including additional controls in the estimation of equation 4.4. I start by including personality traits (patience and risk aversion) and then also implement Chernozhukov et al.'s (2018) double machine-learning partialling-out approach.

Patience has a marginally significant negative effect on income but leaves the education effect unchanged. While this does not rule out that having been to school longer makes people more patient (or more patient individuals go to school longer), there is no evidence that more patient people profit more from

Table 4.7: Returns to education: Worker effect - Robustness tests (confounders)

	Outcome: Average daily income (log)				
	(1)	(2)	(3)	(4)	(5)
Years of education$^\diamondsuit$	0.06***	0.06***	0.06***	0.06***	0.04***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.015)
Years of experience	0.04***	0.04***	0.05***	0.05***	
	(0.015)	(0.015)	(0.015)	(0.015)	
Experience squared	-0.00	-0.00	-0.00*	-0.00*	
	(0.001)	(0.001)	(0.001)	(0.001)	
Female	-0.46***	-0.46***	-0.50***	-0.50***	
	(0.103)	(0.103)	(0.106)	(0.106)	
Item sold = food	-0.25***	-0.26***	-0.24***	-0.24***	
	(0.087)	(0.088)	(0.089)	(0.089)	
Patience (standardized)	-0.08*	-0.12			
	(0.046)	(0.079)			
Education*Patience		0.01			
		(0.011)			
Risk aversion (standardized)			-0.13***	-0.14**	
			(0.047)	(0.065)	
Education*Risk aversion				0.00	
				(0.008)	
Constant	8.32***	8.32***	8.34***	8.34***	0.02
	(0.179)	(0.180)	(0.182)	(0.182)	(0.051)
Observations	987	987	968	968	752
R-squared	0.109	0.109	0.116	0.116	0.009

Standard errors (clustered at the market level) in parentheses; District FE included; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

$^\diamondsuit$ Column 5 presents the education coefficient obtained from Chernozhukov et al.'s (2018) double machine-learning partialling-out estimator.

education in terms of their income (Table 4.7 columns 1 and 2). And risk aversion decreases income. A possible explanation could be that more risk averse individuals make fewer investments or it is the result of the stylized fact that females are more risk averse (and earn less in our sample). Risk attitudes have however no effect on the returns to education. Education does not moderate risk aversion effects on income and risk aversion does not moderate returns to education (see Table 4.7 columns 3 and 4).

Chernozhukov et al.'s (2018) double machine-learning approach to partial out the potentially confounding effects of other covariates from the effect of education on income from self-employment confirms baseline findings. The "pure" effect of an additional year of schooling from which the effects of other covariates have been partialled out amounts to an increase in income of 4 percent (Table

4.7, column 5). This provides further evidence for the claim that education increases worker productivity and thus earnings even within a narrowly defined type of self-employment in a rural developing country setting. In particular, this finding suggests the existence of a true education effect that is not driven by some underlying confounders.

Furthermore, I show that the separate discussion of the channels does not drive the observed returns to education. Even in a regression in which all potential mechanisms are included, I find returns to education still amount to 5 percent per additional years of schooling (Table 4.8 column 6).

In addition, the increased income due to more years of completed education even translates into higher per capita consumption. Coefficients match closely (see Table 4.8 column 5).

4.6.3 Additional considerations - Selection into self-employment

In the sample of market vendors studied in this paper, I do not observe those individuals that follow different activities or do not earn anything at all.[23] If returns to education are different in these other activities and if selection into market vending is influenced by education, the estimated returns to education for market vendors might be biased. While the choice to sample market vendors only does not allow me to formally address selection concerns using the Heckman selection model, I am confident the overall selection into self-employment is not a major source of concern in the present setting for the following reasons. First, while several scholars argue that better educated individuals are more likely to select into off-farm work since education increases entrepreneurial ability (see for ex. Le, 1999; Tao Yang, 1997), this form of selection requires the existence of choice options. Yet, alternative income earning opportunities are often limited in rural agricultural contexts (see for ex. World Bank, 2013). In addi-

[23]Note that I also do not observe earnings for individuals who migrated. Yet, I argue this will not affect estimated returns for two reasons. First, the rural population studied in this paper provides only very limited opportunities for migration and second, migration generally leads to increased returns due to the higher real wages in urban areas (Schultz, 1988). Hence, estimated returns could be seen as lower bound.

Table 4.8: Returns to education: Worker effect - Robustness tests

	avg. daily inc (1)	avg. daily inc (2)	avg. daily inc (3)	avg. daily inc IV Reg (4)	avg. daily cons p.c. (5)	avg. daily inc (6)
Years of education		0.04***	0.02*		0.03***	0.05***
		(0.010)	(0.010)		(0.006)	(0.013)
Highest educ level: some/completed primary	0.36***					
	(0.109)					
Highest educ level: some/completed secondary	0.59***					
	(0.130)					
Highest educ level: Tertiary or University	1.18***					
	(0.220)					
At least 1 yr. of completed education				0.72***		
				(0.230)		
Years of experience	0.04***	0.04***	0.04***	0.03**	-0.00	0.04**
	(0.015)	(0.014)	(0.012)	(0.012)	(0.008)	(0.015)
Experience squared	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
female	-0.48***	-0.44***	-0.30***	-0.48***	-0.10	-0.39***
	(0.101)	(0.102)	(0.099)	(0.094)	(0.068)	(0.113)
Item sold = food	-0.25***	-0.26***	-0.22**	-0.28***	-0.16**	-0.29***
	(0.086)	(0.089)	(0.090)	(0.086)	(0.064)	(0.093)
Ever received fin lit training		0.29***	0.23**			
		(0.093)	(0.099)			
Financial literacy		0.17***	0.14***			0.16***
		(0.052)	(0.052)			(0.053)
Numeracy						-0.05
						(0.057)
Literacy						-0.01
						(0.098)
Business investments (log)			0.11***			
			(0.031)			
Total current savings (log)			0.03***			
			(0.008)			
# of community groups: 1						0.25***
						(0.082)
# of community groups: 2						0.51***
						(0.097)
# of community groups: >= 3						0.63***
						(0.128)
Constant	8.28***	8.37***	6.78***	8.20***	11.38***	8.14***
	(0.207)	(0.192)	(0.429)	(0.267)	(0.109)	(0.221)
Observations	995	993	911	991	1,201	952
R-squared	0.108	0.123	0.172	0.087	0.069	0.143
Hansen J stat				15.46		
Hansen p-value				0.116		

Standard errors (clustered at the market level) in parentheses; District FE included; *** p<0.01, ** p<0.05, * p<0.1

IV-regressions estimated using Lewbel's (2012) method with Uganda's Primary Education reform as additional instrument.

tion, if self-employment is started due to labour market push factors, individual characteristics and in particular human capital play a much smaller role in the selection into entrepreneurship. Second, in their meta study on entrepreneurship selection and performance, Van der Sluis et al. (2008) do not find an effect of education on selection into entrepreneurship.

4.7 Discussion and Conclusion

This paper presents robust evidence for the existence of returns to education for the self-employed in a rural developing country setting. In contrast to much of the existing literature, these returns materialize within one particular self-employment activity and do not rely on dynamic labour market opportunities and occupational choice options. Using a unique sample of market vendors in Western Uganda, I find that one additional year of schooling can be attributed to average daily income increases from market vending by 7 percent. These returns are comparable to what other studies have found for settings in which selection into different types of jobs or sheep skin effects (Kolstad et al., 2014) play a much larger role. In addition, this paper combines several theoretical approaches to investigate the precise mechanisms through which educational returns might arise. It shows that educational returns are the result of an effect on the choice of the higher return sector, credit constraints and the development of different skill sets. Applying Welch's (1970) concept of allocative and productive efficiency effect of education, this paper finds that education stimulates the selection into the higher return vending category. And results from an investigation of the interactions between financial constraints and human capital suggest that higher levels of education help to overcome the barrier posed by financial constraints for choosing the higher return vending activity. Furthermore, this paper finds that both generalized knowledge and business specific skills acquired through schooling raise the market vendor's productive efficiency once sectoral selection is accounted for. These two skill sets are not perfect substitutes for each other. In addition, individuals with larger social capital also receive a higher income from self-employment.

This has two implications. First, even in a context in which schooling standards are not optimal (see for ex. Bold et al., 2017), individuals active in self-employment profit from education. It is not only business specific skills but in particular also the generalized education from which those self-employed seem to profit as they need to perform a multitude of tasks (Lazear, 2004). Similarly, schooling might help the development of the capacity to access and process new information, which in turn raises their productivity (Rosenzweig, 1995).

Second, the insights from this study are relevant for other developing country contexts as well. In the absence of a market-clearing amount of decent (wage) jobs, many poor individuals enter self-employment (Quatraro and Vivarelli, 2014). And this situation is unlikely to change soon. Despite the recent economic growth, self-employment is expected to stay important in many developing country economies (Filmer and Fox, 2014). Understanding which factors can help improve earnings for these self-employed is therefore important to untighten the link between poverty and labour market outcomes (Fields, 2011). This paper has shown that there are economically meaningful returns to education for own account workers even if selection into self-employment is driven by lack of alternatives and not by increased entrepreneurial abilities. Yet, the net effect of schooling on earnings in the entire economy remains to be established. In particular, the analysis based on the present sample is unable to make reliable claims as to whether the observed returns are net gains that would accrue to the entire economy or rather distribution effect. If schooling indeed also increases income for the petty self-employed, then more investments in general human capital (through improved curricula or access to education) might be one promising route towards poverty alleviation. More research on other small-scale self-employment activities will be very informative.

Bibliography

Bibliography

Agrawal, T. and A. Agrawal (2019). Who gains more from education? A comparative analysis of business, farm and wage workers in India. *The Journal of Development Studies 55*(6), 1081–1098.

Amartuvshin, T. (2011). Nutrient consumption and poverty in Mongolia. *Mongolian Population Journal 20*, 61–73.

Anderson, J., C. Learch, and S. Gardner (2016). National survey and segmentation of smallholder households in Uganda. *Understanding Their Demand for Financial, Agricultural and Digital Solutions*.

Arlappa, N., K. Venkaiah, and G. Brahmam (2011). Severe drought and the vitamin a status of rural pre-school children in india. *Disasters 35*(3), 577–586.

Ashenfelter, O., C. Harmon, and H. Oosterbeek (1999). A review of estimates of the schooling/earnings relationship, with tests for publication bias. *Labour Economics 6*(4), 453–470.

Azzarri, C., A. Zezza, B. Haile, and E. Cross (2015). Does livestock ownership affect animal source foods consumption and child nutritional status? evidence from rural uganda. *The Journal of Development Studies 51*(8), 1034–1059.

Barnett, B. J., C. B. Barrett, and J. R. Skees (2008). Poverty traps and index-based risk transfer products. *World Development 36*(10), 1766–1785.

Barouni, M. and S. Broecke (2014). The returns to education in Africa: Some new estimates. *The Journal of Development Studies 50*(12), 1593–1613.

Barrett, C. B. and M. R. Carter (2013). The economics of poverty traps and persistent poverty: Empirical and policy implications. *The Journal of Development Studies 49*(7), 976–990.

Barrett, C. B., M. R. Carter, and P. D. Little (2006). Understanding and reducing persistent poverty in Africa: Introduction to a special issue. *The Journal of Development Studies 42*(2), 167–177.

Barrett, C. B., P. P. Marenya, J. McPeak, B. Minten, F. Murithi, W. Oluoch-Kosura, F. Place, J. C. Randrianarisoa, J. Rasambainarivo, and J. Wangila (2006). Welfare dynamics in rural Kenya and Madagascar. *The Journal of Development Studies 42*(2), 248–277.

Batima, P. (2006). Climate change vulnerability and adaptation in the livestock sector of Mongolia. *International START Secretariat: Washington DC*, 204–209.

Battese, G. E. (1997). A note on the estimation of cobb-douglas production functions when some explanatory variables have zero values. *Journal of agricultural Economics 48*(1-3), 250–252.

Becker, G. S. (1962). Investment in human capital: A theoretical analysis. *Journal of Political Economy 70*(5, Part 2), 9–49.

Bedunah, D. J. and S. M. Schmidt (2004). Pastoralism and protected area management in Mongolia's Gobi Gurvansaikhan National Park. *Development and Change 35*(1), 167–191.

Behrman, J. R., A. D. Foster, and M. R. Rosenzweig (1997). The dynamics of agricultural production and the calorie-income relationship: Evidence from Pakistan. *Journal of Econometrics 77*(1), 187–207.

Berrou, J.-P. and F. Combarnous (2011). Testing lin's social capital theory in an informal African urban economy. *The Journal of Development Studies 47*(8), 1216–1240.

Bertram-Huemmer, V. and K. Kraehnert (2017). Does index insurance help households recover from disaster? evidence from ibli mongolia. *American Journal of Agricultural Economics 100*(1), 145–171.

Birnbaum, A. L. (1968). Some latent trait models and their use in inferring an examinee's ability. *Statistical Theories of Mental Test Scores*.

Block, S. A. (2004). Maternal nutrition knowledge and the demand for micronutrient-rich foods: Evidence from Indonesia. *Journal of Development Studies 40*(6), 82–105.

Bold, T., D. Filmer, G. Martin, E. Molina, B. Stacy, C. Rockmore, J. Svensson, and W. Wane (2017). Enrollment without learning: Teacher effort, knowledge, and skill in primary schools in Africa. *Journal of Economic Perspectives 31*(4), 185–204.

Bor, J., G. H. Cohen, and S. Galea (2017). Population health in an era of rising income inequality: Usa, 1980–2015. *The Lancet 389*(10077), 1475–1490.

Bouis, H. E. and L. J. Haddad (1992). Are estimates of calorie-income fxelasticities too high?: A recalibration of the plausible range. *Journal of Development Economics 39*(2), 333–364.

Calderon, G., L. Iacovone, and L. Juarez (2017). Opportunity versus necessity: Understanding the heterogeneity of female micro-entrepreneurs. *The World Bank Economic Review 30*(Supplement_1), S86–S96.

Card, D. (1999). The causal effect of education on earnings. In *Handbook of Labor Economics*, Volume 3, pp. 1801–1863. Elsevier.

Carletto, C., M. Ruel, P. Winters, and A. Zezza (2015). Farm-level pathways to improved nutritional status: Introduction to the special issue. *Journal of Development Studies 51*(8), 945–957.

Carpena, F., S. Cole, J. Shapiro, and B. Zia (2011). *Unpacking the causal chain of financial literacy*. The World Bank.

Carter, M. R. and C. B. Barrett (2006). The economics of poverty traps and persistent poverty: An asset-based approach. *The Journal of Development Studies 42*(2), 178–199.

Carter, M. R., P. D. Little, T. Mogues, and W. Negatu (2007). Poverty traps and natural disasters in Ethiopia and Honduras. *World Development 35*(5), 835–856.

Caruso, G. and S. Miller (2015). Long run effects and intergenerational transmission of natural disasters: A case study on the 1970 Ancash Earthquake. *Journal of Development Economics 117*, 134–150.

Cavallo, E., S. Galiani, I. Noy, and J. Pantano (2013). Catastrophic natural disasters and economic growth. *Review of Economics and Statistics 95*(5), 1549–1561.

Chernozhukov, V., D. Chetverikov, M. Demirer, E. Duflo, C. Hansen, W. Newey, and J. Robins (2018). Double/debiased machine learning for treatment and structural parameters. *The Econometrics Journal 21*(1), C1–C68.

Costello, A., M. Abbas, A. Allen, S. Ball, S. Bell, R. Bellamy, S. Friel, N. Groce, A. Johnson, M. Kett, et al. (2009). Managing the health effects of climate change: lancet and university college london institute for global health commission. *The Lancet 373*(9676), 1693–1733.

de Janvry, A., M. Fafchamps, and E. Sadoulet (1991). Peasant household behaviour with missing markets: Some paradoxes explained. *Economic Journal 101*(409), 1400–417.

De Onis, M., M. Blössner, and E. Borghi (2012). Prevalence and trends of stunting among pre-school children, 1990–2020. *Public Health Nutrition 15*(1), 142–148.

Deaton, A. (1991). Saving and liquidity constraints. *Econometrica 59*, 1221–1248.

Deaton, A. (1997). *The analysis of household surveys: A microeconometric approach to development policy*. World Bank Publications.

Dercon, S. (2004). Growth and shocks: Evidence from rural Ethiopia. *Journal of Development Economics 74*(2), 309–329.

Dercon, S., J. Hoddinott, and T. Woldehanna (2012). Growth and chronic poverty: Evidence from rural communities in Ethiopia. *The Journal of Development Studies 48*(2), 238–253.

Dohmen, T., A. Falk, D. Huffman, U. Sunde, J. Schupp, and G. G. Wagner (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic Association 9*(3), 522–550.

D'Souza, A. and D. Jolliffe (2013). Food insecurity in vulnerable populations: Coping with food price shocks in Afghanistan. *American Journal of Agricultural Economics 96*(3), 790–812.

Efron, B., T. Hastie, I. Johnstone, R. Tibshirani, et al. (2004). Least angle regression. *The Annals of Statistics 32*(2), 407–499.

Elbers, C., J. W. Gunning, and B. Kinsey (2007). Growth and risk: Methodology and micro evidence. *The World Bank Economic Review 21*(1), 1–20.

Fafchamps, M. and B. Minten (2002). Returns to social network capital among traders. *Oxford Economic Papers 54*(2), 173–206.

Fafchamps, M., C. Udry, and K. Czukas (1998). Drought and saving in West Africa: Are livestock a buffer stock? *Journal of Development Economics 55*(2), 273–305.

FAO (2004). Human energy requirements. report of a joint FAO/WHO/UNU expert consultation. *World Health Organ Tech Rep Ser 1*, 35–50.

FAO, IFAD and WFP (2015). The state of food insecurity in the world 2015. meeting the 2015 international hunger targets: Taking stock of uneven progress.

FAO, IFAD, UNICEF, WFP and WHO (2018). *The state of food security and nutrition in the world 2018: Building climate resilience for food security and nutrition*. Food & Agriculture Organization.

Felbermayr, G. and J. Gröschl (2014). Naturally negative: The growth effects of natural disasters. *Journal of Development Economics 111*, 92–106.

Fernández-Giménez, M. E. (1999). Sustaining the steppes: A geographical history of pastoral land use in Mongolia. *Geographical Review 89*(3), 315–342.

Fernandez-Gimenez, M. E., B. Batkhishig, B. Batbuyan, and T. Ulambayar (2015). Lessons from the dzud: Community-based rangeland management increases the adaptive capacity of Mongolian herders to winter disasters. *World Development 68*, 48–65.

Fields, G. S. (2011). Labor market analysis for developing countries. *Labour Economics 18*, S16–S22.

Filmer, D. and L. Fox (2014). *Youth employment in Sub-Saharan Africa*. The World Bank.

Fossen, F. M. and T. J. Büttner (2013). The returns to education for opportunity entrepreneurs, necessity entrepreneurs, and paid employees. *Economics of Education Review 37*, 66–84.

Gibson, J. and S. Rozelle (2002). How elastic is calorie demand? parametric, nonparametric, and semiparametric results for urban Papua New Guinea. *Journal of Development Studies 38*(6), 23–46.

Giesbert, L. and K. Schindler (2012). Assets, shocks, and poverty traps in rural Mozambique. *World Development 40*(8), 1594–1609.

Gignoux, J. and M. Menéndez (2016). Benefit in the wake of disaster: Long-run effects of earthquakes on welfare in rural Indonesia. *Journal of Development Economics 118*, 26–44.

Gindling, T. and D. Newhouse (2014). Self-employment in the developing world. *World Development 56*, 313–331.

Glewwe, P. (2002). Schools and skills in developing countries: Education policies and socioeconomic outcomes. *Journal of Economic Literature 40*(2), 436–482.

Goodland, A., D. Sheehy, and T. Shine (2009). Mongolia livestock sector study, volume i–synthesis report. *Sustainable Development Department, East Asia and Pacific Region, World Bank, Washington, DC*.

Greene, W. H. (2000). *Econometric Analysis* (3 ed.). New Jersey, USA: Prentice Hall.

Groppo, V. and K. Kraehnert (2016). Extreme weather events and child height: evidence from Mongolia. *World Development 86*, 59–78.

Groppo, V. and K. Kraehnert (2017). The impact of extreme weather events on education. *Journal of Population Economics 30*(2), 433–472.

Hallegatte, S., M. Bangalore, L. Bonzanigo, M. Fay, T. Kane, U. Narloch, J. Rozenberg, D. Treguer, and A. Vogt-Schilb (2015). *Shock waves: managing the impacts of climate change on poverty*. The World Bank.

Hallegatte, S., A. Vogt-Schilb, M. Bangalore, and J. Rozenberg (2017). *Unbreakable: Building the resilience of the poor in the face of natural disasters*. World Bank, Washington DC.

Hanna, R. and P. Oliva (2016). Implications of climate change for children in developing countries. *The Future of Children*, 115–132.

Hausman, J. A. and W. E. Taylor (1981). Panel data and unobservable individual effects. *Econometrica: Journal of the Econometric Society*, 1377–1398.

Heckman, J. J., L. J. Lochner, and P. E. Todd (2006). Earnings functions, rates of return and treatment effects: The Mincer equation and beyond. *Handbook of the Economics of Education 1*, 307–458.

Hertel, T. W. and S. D. Rosch (2010). Climate change, agriculture and poverty. *Applied Economic Perspectives and Policy 32*(3), 355–385.

Hoddinott, J., D. Headey, and M. Dereje (2015). Cows, missing milk markets, and nutrition in rural Ethiopia. *The Journal of Development Studies 51*(8), 958–975.

Hundley, G. (2001). Why women earn less than men in self-employment. *Journal of Labor Research 22*(4), 817–829.

International Federation of Red Cross and Red Crescent Societies (IFRC), Mongolian Red Cross Society (MRCS) (2010). Rapid assessment of dzud situation in mongolia (january 18–january 26, 2010): Summary report. IFRC and MRCS, Ulan Bator.

Iversen, J., N. Malchow-Møller, and A. Sørensen (2010). Returns to schooling in self-employment. *Economics Letters 109*(3), 179–182.

Jalan, J. and M. Ravallion (2002). Geographic poverty traps? a micro model of consumption growth in rural China. *Journal of Applied Econometrics 17*(4), 329–346.

Janzen, S. A. and M. R. Carter (2013). After the drought: The impact of microinsurance on consumption smoothing and asset protection. Technical report, National Bureau of Economic Research.

Kaiser, T. and L. Menkhoff (2018). Active learning fosters financial behavior: Experimental evidence. *DIW Discussion Paper 1743*.

Kazianga, H. (2006). Motives for household private transfers in Burkina Faso. *Journal of Development Economics 79*(1), 73–117.

Kellenberg, D. and A. M. Mobarak (2011). The economics of natural disasters. *Annual Review of Resource Economics 3*(1), 297–312.

Kiranda, Y., M. Walter, and M. Mugisha (2017). *Reality Check: Employment, Entrepreneurship and Education in Uganda*. Konrad-Adenauer-Stiftung.

Klapper, L. F. and S. C. Parker (2010). Gender and the business environment for new firm creation. *The World Bank Research Observer 26*(2), 237–257.

Kolstad, I. and A. Wiig (2013). Is it both what you know and who you know? human capital, social capital and entrepreneurial success. *Journal of International Development 25*(5), 626–639.

Kolstad, I. and A. Wiig (2015). Education and entrepreneurial success. *Small Business Economics 44*(4), 783–796.

Kolstad, I., A. Wiig, and K. G. Moazzem (2014). Returns to education among entrepreneurs in Bangladesh. *Journal of Asian Economics 34*, 54–65.

Kraay, A. and D. McKenzie (2014). Do poverty traps exist? Assessing the evidence. *The Journal of Economic Perspectives 28*(3), 127–148.

Kumar, N., J. Harris, and R. Rawat (2015). If they grow it, will they eat and grow? evidence from Zambia on agricultural diversity and child undernutrition. *The Journal of Development Studies 51*(8), 1060–1077.

Laszlo, S. (2005). Self-employment earnings and returns to education in rural Peru. *Journal of Development Studies 41*(7), 1247–1287.

Lazear, E. P. (2004). Balanced skills and entrepreneurship. *American Economic Review 94*(2), 208–211.

Le, A. T. (1999). Empirical studies of self-employment. *Journal of Economic Surveys 13*(4), 381–416.

Lehmann-Uschner, K. and K. Kraehnert (2017). Food intake and the role of food self-provisioning. *The Journal of Development Studies 53*(8), 1303–1322.

Lewbel, A. (2012). Using heteroscedasticity to identify and estimate mismeasured and endogenous regressor models. *Journal of Business & Economic Statistics 30*(1), 67–80.

Loayza, N. V., E. Olaberria, J. Rigolini, and L. Christiaensen (2012). Natural disasters and growth: Going beyond the averages. *World Development 40*(7), 1317–1336.

Lokshin, M. and M. Ravallion (2004). Household income dynamics in two transition economies. *Studies in Nonlinear Dynamics & Econometrics 8*(3).

Lord, F. M. (2012). *Applications of item response theory to practical testing problems*. Routledge.

Lusardi, A. and O. S. Mitchell (2014). The economic importance of financial literacy: Theory and evidence. *Journal of Economic Literature 52*(1), 5–44.

Lybbert, T. J., C. B. Barrett, S. Desta, and D. Layne Coppock (2004). Stochastic wealth dynamics and risk management among a poor population. *The Economic Journal 114*(498), 750–777.

Mahul, O. and J. R. Skees (2007). Managing agricultural risk at the country level: The case of index-based livestock insurance in Mongolia. World Bank Policy Research Paper 4325.

McKay, A. and E. Perge (2013). How strong is the evidence for the existence of poverty traps? A multicountry assessment. *The Journal of Development Studies 49*(7), 877–897.

McPeak, J. (2006). Confronting the risk of asset loss: What role do livestock transfers in northern Kenya play? *Journal of Development Economics 81*(2), 415–437.

McPeak, J. G. and C. B. Barrett (2001). Differential risk exposure and stochastic poverty traps among east african pastoralists. *American Journal of Agricultural Economics 83*(3), 674–679.

Michelson, H., M. Muñiz, and K. DeRosa (2013). Measuring socio-economic status in the millennium villages: The role of asset index choice. *The Journal of Development Studies 49*(7), 917–935.

Mincer, J. (1958). Investment in human capital and personal income distribution. *Journal of Political Economy 66*(4), 281–302.

Mincer, J. (1974). Schooling, experience, and earnings. human behavior & social institutions no. 2.

Muller, C. (2009). Do agricultural outputs of partly autarkic peasants affect their health and nutrition? evidence from rwanda. *Food Policy 34*(2), 166–175.

Murphy, D. J. (2011). Going on otor: Disaster, mobility, and the political ecology of vulnerability in Uguumur, Mongolia. PhD dissertation, University of Kentucky.

Nagler, P. and W. Naudé (2014). Non-farm entrepreneurship in rural Africa: patterns and determinants. *IZA Discussion Paper*.

Naschold, F. (2012). "the poor stay poor": Household asset poverty traps in rural semi-arid India. *World Development 40*(10), 2033–2043.

National Statistical Office of Mongolia (2003). Mongolian statistical yearbook 2002. NSO, Ulaanbaatar.

National Statistical Office of Mongolia (2013). Mongolian statistical yearbook 2012. NSO, Ulaanbaatar.

Pachauri, R. K., M. R. Allen, V. R. Barros, J. Broome, W. Cramer, R. Christ, J. A. Church, L. Clarke, Q. Dahe, P. Dasgupta, et al. (2014). *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*. IPCC.

Paulson, A. L. and R. Townsend (2004). Entrepreneurship and financial constraints in Thailand. *Journal of Corporate Finance 10*(2), 229–262.

Peet, E. D., G. Fink, and W. Fawzi (2015). Returns to education in developing countries: Evidence from the living standards and measurement study surveys. *Economics of Education Review 49*, 69–90.

Pitt, M. M. and M. R. Rosenzweig (1985). Health and nutrient consumption across and within farm households. *The Review of Economics and Statistics*, 212–223.

Psacharopoulos, G. and H. A. Patrinos (2004). Returns to investment in education: A further update. *Education Economics 12*(2), 111–134.

Quatraro, F. and M. Vivarelli (2014). Drivers of entrepreneurship and post-entry performance of newborn firms in developing countries. *The World Bank Research Observer 30*(2), 277–305.

Quisumbing, A. R. and B. Baulch (2013). Assets and poverty traps in rural Bangladesh. *The Journal of Development Studies 49*(7), 898–916.

Rasch, G. (1960). Studies in mathematical psychology: I. probabilistic models for some intelligence and attainment tests.

Rosenzweig, M. R. (1995). Why are there returns to schooling? *The American Economic Review 85*(2), 153–158.

Rosenzweig, M. R. and K. I. Wolpin (1993). Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: Investments in bullocks in India. *Journal of Political Economy 101*(2), 223–244.

Ruel, M. T., H. Alderman, Maternal, C. N. S. Group, et al. (2013). Nutrition-sensitive interventions and programmes: How can they help to accelerate progress in improving maternal and child nutrition? *The Lancet 382*(9891), 536–551.

Sahn, D. E. and D. Stifel (2003). Exploring alternative measures of welfare in the absence of expenditure data. *Review of Income and Wealth 49*(4), 463–489.

Salois, M. J., R. Tiffin, and K. G. Balcombe (2012). Impact of income on nutrient intakes: Implications for undernourishment and obesity. *The Journal of Development Studies 48*(12), 1716–1730.

Schultz, T. P. (1988). Education investments and returns. *Handbook of Development Economics 1*, 543–630.

Seneviratne, S. I., N. Nicholls, D. Easterling, C. M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, et al. (2012). Changes in climate extremes and their impacts on the natural physical environment. In *Managing the risks of extreme events and disasters to advance climate change adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC)*, pp. 109–230. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

Shekar, M., R. Heaver, Y.-K. Lee, et al. (2006). *Repositioning nutrition as central to development: A strategy for large scale action*. World Bank Publications.

Shively, G. and C. Sununtnasuk (2015). Agricultural diversity and child stunting in Nepal. *The Journal of Development Studies 51*(8), 1078–1096.

Singh, I., L. Squire, J. Strauss, et al. (1986). *Agricultural household models: Extensions, applications, and policy*. Johns Hopkins University Press Baltimore.

Skees, J. R. and A. Enkh-Amgalan (2002). *Examining the feasibility of livestock insurance in Mongolia*, Volume 2886. World Bank Publications.

Skoufias, E., V. Di Maro, T. González-Cossío, and S. R. Ramirez (2009). Nutrient consumption and household income in rural Mexico. *Agricultural Economics 40*(6), 657–675.

Slavchevska, V. (2015). Agricultural production and the nutritional status of family members in Tanzania. *The Journal of Development Studies 51*(8), 1016–1033.

Sternberg, T. (2010). Unravelling Mongolia's extreme winter disaster of 2010. *Nomadic Peoples 14*(1), 72–86.

Strauss, J. and D. Thomas (1995). Human resources: Empirical modeling of household and family decisions. *Handbook of Development Economics 3*, 1883–2023.

Strauss, J. and D. Thomas (1998). Health, nutrition, and economic development. *Journal of Economic Literature 36*(2), 766–817.

Strobl, E. (2012). The economic growth impact of natural disasters in developing countries: Evidence from hurricane strikes in the Central American and Caribbean regions. *Journal of Development economics 97*(1), 130–141.

Tao Yang, D. (1997). Education and off-farm work. *Economic Development and Cultural Change 45*(3), 613–632.

Tasciotti, L. and N. Wagner (2015). Urban agriculture and dietary diversity: Empirical evidence from Tanzania. *The European Journal of Development Research 27*(5), 631–649.

Tchakerian, V. (2015). Hydrology, floods and droughts — deserts and desertification. In G. R. North, J. Pyle, and F. Zhang (Eds.), *Encyclopedia of Atmospheric Sciences (Second Edition)* (Second Edition ed.)., pp. 185 – 192. Oxford: Academic Press.

Toth, R. (2014). Traps and thresholds in pastoralist mobility. *American Journal of Agricultural Economics 97*(1), 315–332.

Uganda Bureau of Statistics (2018). *The National Labour Force Survey 2016/17 – Main Report*. Kampala, Uganda.

United Nations Office for Disaster Risk Reduction (2015). The human cost of weather-related disasters 1995-2015. United Nations Office for Disaster Risk Reduction, Geneva and Centre for Research on the Epidemiology of Disasters, Brussels.

Van der Sluis, J., M. Van Praag, and W. Vijverberg (2005). Entrepreneurship selection and performance: A meta-analysis of the impact of education in developing economies. *The World Bank Economic Review 19*(2), 225–261.

Van der Sluis, J., M. Van Praag, and W. Vijverberg (2008). Education and entrepreneurship selection and performance: A review of the empirical literature. *Journal of Economic Surveys 22*(5), 795–841.

Verpoorten, M. (2009). Household coping in war-and peacetime: Cattle sales in Rwanda, 1991–2001. *Journal of Development Economics 88*(1), 67–86.

Victora, C. G., L. Adair, C. Fall, P. C. Hallal, R. Martorell, L. Richter, H. S. Sachdev, Maternal, C. U. S. Group, et al. (2008). Maternal and child undernutrition: Consequences for adult health and human capital. *The Lancet 371*(9609), 340–357.

Vijverberg, W. P. (1986). Consistent estimates of the wage equation when individuals choose among income-earning activities. *Southern Economic Journal*, 1028–1042.

Villa, K. M., C. B. Barrett, and D. R. Just (2010). Differential nutritional responses across various income sources among east african pastoralists: Intrahousehold effects, missing markets and mental accounting. *Journal of African Economies 20*(2), 341–375.

Von Grebmer, K., A. Saltzman, E. Birol, D. Wiesmann, N. Prasai, Y. Yohannes, P. Menon, J. Thompson, and A. Sonntag (2014). Global hunger index 2014: The challenge of hidden hunger. *Bonn/Washington DC/Dublin: Welthungerhilfe, International Food Policy Research Institute (IFPRI), Concern Worldwide*.

Weiss, A. (1995). Human capital vs. signalling explanations of wages. *Journal of Economic Perspectives 9*(4), 133–154.

Welch, F. (1970). Education in production. *Journal of Political Economy 78*(1), 35–59.

Winsemius, H. C., B. Jongman, T. I. Veldkamp, S. Hallegatte, M. Bangalore, and P. J. Ward (2018). Disaster risk, climate change, and poverty: Assessing the global exposure of poor people to floods and droughts. *Environment and Development Economics 23*(3), 328–348.

World Bank (2010). World Development Report 2010: Development and climate change. World Bank, Washington DC.

World Bank (2013). *Uganda Economic Update August 2013 - Jobs: Key to Prosperity*. Washington, DC.

Yang, D. T. and M. Y. An (2002). Human capital, entrepreneurship, and farm household earnings. *Journal of Development Economics 68*(1), 65–88.

Zimmerman, F. J. and M. R. Carter (2003). Asset smoothing, consumption smoothing and the reproduction of inequality under risk and subsistence constraints. *Journal of Development Economics 71*(2), 233–260.

Appendix A: Appendix for Chapter 2

Data

The HIES/LSMS data is an intersection of two separate surveys: The HIES recorded household consumption and income over a period of three consecutive months as well as basic household demographics. The HIES was implemented between February 2002 and January 2003, with roughly an equal share of households interviewed every month.[24] Building on the 2000 population census as the sampling frame, a two-stage stratified survey design was used to draw the HIES sample, which comprises of approximately 11,200 households. The LSMS revisited a random subsample of 3,308 households between March and July 2003, on average nine months after the HIES interview took place. The LSMS questionnaire captures the socio-economic status of the sampled households in great detail. The sample of households analysed here was interviewed in both HIES and LSMS. All analyses presented in the following account for the survey design and use population weights.

The HIES data provide a very detailed record of food consumption. Each household in the sample was asked to fill in a consumption diary for three consecutive months, which the enumerators left with the households during their first visit.[25] The diary documents the quantity consumed, purchased, self-produced within the household, sold, received as gift, and given away as gift for 92 food items across 10 categories: (i) meat and meat products; (ii) milk and dairy products; (iii) flour and flour products; (iv) vegetables; (v) fruits; (vi) sweets; (vii) tea, coffee and beverages; (viii) spices; (ix) alcohol and tobacco; as well as (x) meals eaten away from home. The outcome of interest is the quantity consumed per household, which we adjust to the number of guests staying overnight. We then aggregate the nutrients included in the various food items consumed within the household. This is done using food composition tables prepared by the Mongolian Ministry of Health in 2009 that contain the nutri-

[24]One particularity of the data is that the HIES was implemented on a quarterly basis. That is, 25 percent of the sample households were interviewed in the first quarter of 2002; another 25 percent of households were interviewed in the second quarter of 2002 and so on. In each quarter, households were interviewed in all provinces and in all strata.

[25]In the months of February and July, the consumption of food and non-food items is exceptionally high, as two major festivities take place during these months. To avoid bias stemming from considering different numbers of months per household, we also omit observations from the first month of the other two quarters (April and October) from the analysis.

ent value per 100 gram or millilitre. Food consumed outside the homestead is excluded, as information on the nutritional content is not available.[26] The total amount of nutrients consumed in the household is then scaled to household composition.[27]

The measures obtained indicate the quantity of nutrients consumed per day per adult equivalent. It is important to note that these measures do not represent actual food consumed per individual, as it is not observed how food is allocated among household members. Instead, the measures represent proxies for food consumption, assuming that food was shared according to the age factors used in calculating adult equivalent ratios. Great care was given to perform quality checks and detect potential outliers in the nutrition variables. Following common practice in the literature (for ex. FAO, 2004; Skoufias et al., 2009), we exclude all observations exhibiting daily per adult equivalents of calories consumption below 500 or above 6000 calories. The NSO has implemented HIES regularly since the 1960s, thus both the diary design, the choice of food items recorded, as well as data collection and processing procedures are settled. This underscores the reliability of the nutrition data.

Households also recorded their monthly income on the survey diaries. More specifically, the diaries asked for five income components, which we then added

[26]The lack of data on the nutritional content of the food consumed outside the homestead underestimates the total amount of nutrients consumed. We attempted to explore the magnitude of this problem by multiplying the monetary value of the food consumed outside the home with the average amount of calories contained in food worth of 1,000 Mongolian tugrik (MNT). This test should only be considered a very rough approximation, assuming that the food consumed outside home is of the same quality compared to food consumed inside the household. About 32 percent, 21 percent, and 14 percent of non-herding households, small-scale herders and large-scale herders, respectively, did consume food outside the household. Yet, households spent a very low amount of money on food outside the home. Similarly, the amount of calories consumed and hence the adequacy ratio in calories consumption increases by only about 5 percent for non-herding households when considering food consumed outside home. When re-estimating the determinants of calories intake with the modified calories variable, all main results are maintained. As expected, the point estimates for income increase slightly (since income should matter even more for food consumed outside home than food consumed inside home). However, the differences between the regression including and excluding consumption outside the homestead are not statistically significant.

[27]Following Deaton (1997), individuals aged 15 and above are considered to be adults (and assigned the factor 1), while children between 0 and 4 years of age receive the factor 0.4 and children between 5 and 14 years receive the factor 0.5.

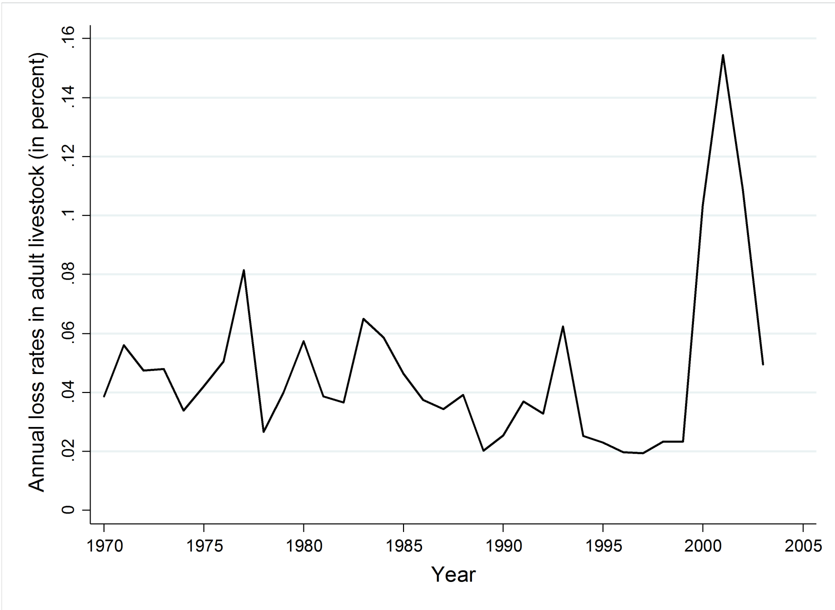
together as total household income: income derived from wage work, non-agricultural enterprise, transfers, herding, and farming. We adjusted household income for seasonal and locational price differences, using a Paasche price index. Income is expressed in adult equivalents and normalized by the number of days per month. We exclude households below the 1st percentile and above the 99th percentile of the distribution of income. This leaves us with a sample of 2,788 households.

Based on the diaries, we also calculate households' expenditures on food and non-food consumption. The food component of expenditures consists of food purchases and self-provisioned food. To derive a monetary value of self-provisioned food, we first calculate unit prices for all food items that are purchased in markets across various administrative levels (enumeration area, sub-district, district, province, and country) for every month of the year. The quantity of self-provisioned food is then multiplied with the unit price at the lowest level for which prices are reported from at least eight households. For food items for which very few households reported prices or for which reported prices showed a high spread, we rely on the quarterly food price survey that collects shop prices of various food items at the district level. The non-food component of expenditures consists of household expenses for 242 items that were recorded in the consumption diary. These include education, health, clothing, jewellery, recreation, household goods, durables, housing, transportation, and communication. The total value of household consumption expenditure is again expressed in adult equivalents, normalized per day, and adjusted for seasonal and locational price differences.

Information on durable ownership – which is used for a robustness test – is obtained from the LSMS questionnaire, which records the current monetary value of an extensive list of 47 durables that include home appliances, furniture, electronic equipment, means of transportation, jewellery, and dwelling. The total value of all items owned was aggregated into one measure. For herders, we additionally control for the number of animals owned.

Figures and Tables

Figure A.1: Livestock loss rates in Mongolia, 1970-2003



Source: Authors' calculations based on the Mongolia Livestock Census.

Table A.1: Comparing characteristics across households

	Mean values (standard errors in parentheses)			P-values from tests on differences in means		
	(1) Small-scale herding households N=1,332	(2) Large-scale herding households N=449	(3) Non-herding households N=1,007	(1)-(2)	(1)-(3)	(2)-(3)
Wealth						
Consumption expend. per adult equivalent per month[a]	27.40	31.88	25.73	0.00***	0.10	0.00***
	(0.69)	(1.26)	(0.78)			
Income per adult equivalent per month[a]	24.77	28.38	27.04	0.06*	0.05*	0.51
	(0.81)	(1.85)	(0.93)			
Share of income from wage work	0.33	0.15	0.50	0.00***	0.00***	0.00***

Continued on next page...

... table A.1 continued

	Mean values (standard errors in parentheses)			P-values from tests on differences in means		
	(1)	(2)	(3)	(1)-(2)	(1)-(3)	(2)-(3)
	Small-scale herding households	Large-scale herding households	Non-herding households			
	N=1,332	N=449	N=1,007			
	(0.02)	(0.02)	(0.02)			
Share of income from herding	0.23	0.49	0	0.00***		
	(0.02)	(0.03)				
Share of income from non-herding self-employment	0.19	0.15	0.22	0.03**	0.05*	0.00***
	(0.01)	(0.02)	(0.01)			
Share of income from transfers	0.23	0.20	0.27	0.03**	0.01**	0.00***
	(0.01)	(0.02)	(0.01)			
Value of durables per adult equivalent[a]	886.01	690.51	2065.35	0.01**	0.00***	0.00***
	(64.32)	(40.57)	(162.02)			
Number of livestock per adult equivalent	11.60	54.51	0	0.00***		
	(0.32)	(2.20)				
Socio-demographic characteristics						
Household size	5.24	5.35	5.17	0.32	0.50	0.13
	(0.07)	(0.09)	(0.09)			
Share of children below age 6	0.10	0.11	0.08	0.59	0.00***	0.01**
	(0.00)	(0.01)	(0.00)			
Female household head	0.11	0.08	0.18	0.11	0.00***	0.00***
	(0.01)	(0.01)	(0.01)			
Years of education of most senior woman	9.44	8.67	10.69	0.00***	0.00***	0.00***
	(0.11)	(0.19)	(0.14)			
Age of household head	44.10	43.82	46.19	0.77	0.00***	0.00***
	(0.43)	(0.68)	(0.52)			
Location of residence						
Ulaanbaatar	0.17	0.00	0.64	0.00***	0.00***	0.00***
	(0.02)	(0.00)	(0.02)			
Provincial centre	0.26	0.14	0.30	0.00***	0.26	0.00***
	(0.02)	(0.03)	(0.02)			
District centre	0.24	0.19	0.05	0.10	0.00***	0.00***
	(0.02)	(0.02)	(0.02)			
Countryside	0.33	0.67	0.01	0.00***	0.00***	0.00***
	(0.02)	(0.03)	(0.00)			
Market access						
Distance to nearest water source (in km)	0.84	1.62	0.46	0.00***	0.00***	0.00***

Continued on next page...

... table A.1 continued

	Mean values (standard errors in parentheses)			P-values from tests on differences in means		
	(1) Small-scale herding households N=1,332	(2) Large-scale herding households N=449	(3) Non-herding households N=1,007	(1)-(2)	(1)-(3)	(2)-(3)
	(0.07)	(0.20)	(0.07)			
Distance to nearest health centre (in km)	6.69	15.97	0.86	0.00***	0.00***	0.00***
	(0.57)	(1.30)	(0.05)			
Vehicle ownership	0.30	0.55	0.19	0.00***	0.00***	0.00***
	(0.02)	(0.03)	(0.02)			
Food self-provisioning						
Share of calories from own animal husbandry	0.20	0.35	0	0.00***		
	(0.01)	(0.01)				
Share of meat from own animal husbandry (out of total consumed meat)	0.57	0.86	0	0.00***		
	(0.02)	(0.01)				
Share of calories from meat	0.23	0.29	0.14	0.00***	0.00***	0.00***
	(0.01)	(0.01)	(0.00)			
Share of consumed dairy products from own animal husbandry (out of total consumed dairy products)	0.44	0.72	0	0.00***		
	(0.02)	(0.03)				
Share of calories from dairy products	0.09	0.12	0.05	0.00***	0.00***	0.00***
	(0.01)	(0.01)	(0.00)			
Consumed crops from own farming	0.23	0.26	0.05	0.24	0.00***	0.00***
	(0.02)	(0.03)	(0.01)			
Share of calories from own farming	0.02	0.04	0.00	0.01**	0.00***	0.00***
	(0.00)	(0.01)	(0.00)			
Share of total monthly expenditures spent on food	0.63	0.63	0.54	0.92	0.00***	0.00***
	(0.01)	(0.01)	(0.01)			

[a] in 1,000 MNT. Colums 4-6 show p-values on tests on differences in means between the three groups of households. T-tests are used for continuous variables, chi-square tests for non-continuous variables with *** p<0.01, ** p<0.05, * p<0.1. For each household, two months of data from consumption diaries are used. Observations from February, April, July and October are excluded. Source: HIES/LSMS 2002/03.

Table A.2: Marginal *dzud* effects on nutrient intake at different intensities of food self-provisioning

Dependent Variable	Calories	Carbo-hydrates	Animal proteins	Vegetal proteins	Animal fat	Vegetal fat	Iron	Vitamin A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A1: Small-scale herding households - Farming								
10^{th} percentile	0.01	0.03	0.02	0.00	-0.14**	-0.07	-0.04	0.04
	(0.034)	(0.037)	(0.067)	(0.038)	(0.070)	(0.092)	(0.036)	(0.053)
25^{th} percentile	0.00	0.02	0.01	-0.01	-0.15**	-0.06	-0.05	0.03
	(0.033)	(0.035)	(0.063)	(0.037)	(0.066)	(0.089)	(0.034)	(0.050)
50^{th} percentile	-0.03	-0.01	-0.03	-0.02	-0.16***	-0.06	-0.06*	-0.02
	(0.030)	(0.030)	(0.054)	(0.032)	(0.056)	(0.080)	(0.033)	(0.045)
75^{th} percentile	-0.06*	-0.05*	-0.07	-0.05	-0.17***	-0.06	-0.07	-0.07
	(0.033)	(0.030)	(0.051)	(0.032)	(0.049)	(0.076)	(0.042)	(0.049)
90^{th} percentile	-0.09**	-0.09**	-0.11*	-0.07*	-0.18***	-0.05	-0.08	-0.12**
	(0.041)	(0.035)	(0.057)	(0.037)	(0.051)	(0.079)	(0.056)	(0.060)
Panel A2: Small-scale herding households - Non-farmers								
10^{th} percentile	0.00	0.03	0.01	0.01	-0.11	-0.03	0.00	0.06
	(0.038)	(0.038)	(0.058)	(0.040)	(0.070)	(0.079)	(0.044)	(0.047)
25^{th} percentile	-0.01	0.02	-0.00	0.00	-0.11*	-0.03	-0.00	0.04
	(0.036)	(0.036)	(0.054)	(0.038)	(0.067)	(0.076)	(0.040)	(0.043)
50^{th} percentile	-0.04	-0.02	-0.04	-0.02	-0.13**	-0.03	-0.01	-0.00
	(0.032)	(0.031)	(0.045)	(0.032)	(0.059)	(0.065)	(0.033)	(0.034)
75^{th} percentile	-0.07**	-0.06*	-0.08*	-0.04	-0.14**	-0.03	-0.02	-0.06
	(0.033)	(0.031)	(0.045)	(0.031)	(0.056)	(0.061)	(0.034)	(0.036)
90^{th} percentile	-0.09**	-0.09***	-0.12**	-0.06*	-0.15**	-0.02	-0.03	-0.11**
	(0.039)	(0.036)	(0.054)	(0.034)	(0.061)	(0.065)	(0.045)	(0.049)
Panel B1: Large-scale herding households - Farming								
10^{th} percentile	-0.00	-0.00	0.01	-0.01	-0.13***	-0.03	0.00	0.10
	(0.028)	(0.028)	(0.049)	(0.033)	(0.041)	(0.072)	(0.047)	(0.060)
25^{th} percentile	-0.01	-0.00	-0.00	-0.01	-0.10***	-0.01	-0.01	0.07
	(0.029)	(0.028)	(0.051)	(0.034)	(0.034)	(0.075)	(0.053)	(0.056)
50^{th} percentile	-0.02	-0.01	-0.01	-0.00	-0.07**	0.02	-0.03	0.03
	(0.034)	(0.033)	(0.061)	(0.041)	(0.034)	(0.084)	(0.063)	(0.060)
75^{th} percentile	-0.03	-0.01	-0.03	0.00	-0.04	0.04	-0.04	-0.01
	(0.043)	(0.041)	(0.076)	(0.053)	(0.042)	(0.099)	(0.077)	(0.072)
90^{th} percentile	-0.03	-0.01	-0.04	0.01	-0.01	0.06	-0.06	-0.04
	(0.051)	(0.049)	(0.089)	(0.063)	(0.051)	(0.112)	(0.088)	(0.085)
Panel B2: Large-scale herding households - Non-farmers								
10^{th} percentile	-0.01	-0.01	0.02	-0.01	-0.11	-0.01	0.03	0.08*
	(0.021)	(0.024)	(0.042)	(0.028)	(0.036)	(0.044)	(0.027)	(0.049)
25^{th} percentile	-0.01	-0.01	0.01	-0.01	-0.09***	0.02	0.02	0.05
	(0.021)	(0.023)	(0.044)	(0.028)	(0.029)	(0.039)	(0.028)	(0.046)
50^{th} percentile	-0.02	-0.01	-0.00	-0.00	-0.05*	0.04	-0.00	0.02
	(0.028)	(0.028)	(0.054)	(0.035)	(0.029)	(0.045)	(0.038)	(0.052)
75^{th} percentile	-0.03	-0.01	-0.02	0.00	-0.02	0.06	-0.02	-0.02
	(0.038)	(0.037)	(0.070)	(0.047)	(0.039)	(0.061)	(0.052)	(0.067)
90^{th} percentile	-0.04	-0.01	-0.02	0.01	0.01	0.08	-0.03	-0.05
	(0.047)	(0.045)	(0.084)	(0.058)	(0.050)	(0.076)	(0.064)	(0.082)

This table displays the marginal effect of the *dzud* at different values (meaning percentiles of the distribution) of the calorie share consumed from own production. The full regression results from which these marginal effects are obtained are displayed in Table 2.6

Appendix B: Appendix for Chapter 3

Table B.1: Determinants of household-level livestock mortality in 2010 in horse units (Generalized linear model using the logit link)

	Outcome: Household-level livestock mortality in 2010 in horse units, in percent							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dzud intensity								
Mortality (district)	0.72***			0.57***	0.75***	0.75***	0.72***	0.71***
	(0.079)			(0.081)	(0.079)	(0.079)	(0.079)	(0.079)
Mortality (sub-distr.)		0.50***						
		(0.073)						
Winter temperature (district)			0.54***					
			(0.108)					
Winter temperature squared			0.23***					
			(0.046)					
Pre-shock herd characteristics								
Herd size in 2009 in horse units (in log)	-0.14***	-0.13***	-0.12***		-0.12***	-0.12***	-0.14***	-0.14***
	(0.011)	(0.011)	(0.011)		(0.011)	(0.011)	(0.011)	(0.011)
Herd size in 2009 btw 50 and 99				0.03				
				(0.056)				
Herd size in 2009 btw 100 and 199				0.04				
				(0.049)				
Herd size in 2009 greater 199				0.08*				
				(0.049)				
Share of goats in 2009					-0.34***	-0.34***		
					(0.052)	(0.052)		
Experience								
Parents of head were herders	-0.03	-0.03	-0.04	-0.08	-0.05	-0.05	-0.03	-0.03
	(0.052)	(0.050)	(0.052)	(0.055)	(0.051)	(0.051)	(0.052)	(0.052)
Head always lived in current district	-0.03	-0.06**	-0.04	-0.05	-0.03	-0.01	-0.03	-0.02
	(0.028)	(0.028)	(0.028)	(0.032)	(0.026)	(0.027)	(0.028)	(0.028)
Head was full-time herder in 2009	0.02	0.01	0.01	-0.06	0.01	0.01	0.01	0.01
	(0.032)	(0.032)	(0.030)	(0.039)	(0.030)	(0.030)	(0.035)	(0.032)
Spouse was full-time herder in 2009	-0.01	-0.01	-0.02	-0.05	-0.02	-0.02	-0.01	-0.01
	(0.026)	(0.026)	(0.025)	(0.029)	(0.025)	(0.024)	(0.026)	(0.026)
Herding during the 2000-2002 *dzuds*							0.02	
							(0.040)	
Shock coping in 2010								
Temporary migration								-0.01
								(0.022)
Household sold livestock								0.03
								(0.025)
Volatility and stocking density								
Volatility in livestock population (distr.)	-0.00	0.00	0.01**	0.00	0.00	0.00	-0.00	-0.00
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Stocking density (district)						0.01		
						(0.008)		
Household characteristics								
Age of head	0.00***	0.00***	0.00***	0.00**	0.00**	0.00*	0.00***	0.00***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Female head	0.00	-0.00	0.02	0.07	0.01	0.02	-0.00	0.00
	(0.046)	(0.045)	(0.040)	(0.044)	(0.041)	(0.041)	(0.046)	(0.046)
Secondary or higher education	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	(0.020)	(0.020)	(0.020)	(0.022)	(0.020)	(0.020)	(0.020)	(0.020)
Lived in rural area in 2009	0.05**	0.05**	0.03	0.06**	0.03	0.03	0.05*	0.05*
	(0.024)	(0.024)	(0.024)	(0.026)	(0.024)	(0.024)	(0.024)	(0.024)
District characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	Province	Province	Province	Province	Province	Province	Province	Province
Observations	882	882	882	882	882	874	882	882

Model estimated as generalized linear model using the logit link. The table reports marginal effects obtained using the delta method and standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%, ** significant at 5%, *** significant at 1%. In column 4, the excluded category is herd size in 2009 between 1 and 49 animals. One horse unit is equivalent to one cow, 0.67 camels, six sheep, or eight goats. Source: Coping with Shocks in Mongolia Household Panel Survey, and Mongolia Livestock Census.

Table B.2: Annual livestock growth rates 2012-2015 in horse units (Hausman-Taylor estimator)

	Outcome: Livestock growth rates		
	(1)	(2)	(3)
Dzud intensity			
Livestock mortality in 2010 (hh) (log)[a]	-0.85***	-0.93***	-0.82***
	(0.206)	(0.241)	(0.190)
Mortality covariance in 2010 (distr.)		0.48	
		(1.117)	
Morality covariance*livestock mortality (hh)		-1.06	
		(1.037)	
% of HHs with zero *dzud*-losses (distr.)			0.27
			(1.366)
Zero *dzud*-losses*livestock mortality (hh)			0.76
			(1.197)
Beginning-of-year herd characteristics			
Herd size (log)[b]$^{\diamondsuit}$	-1.70***	-1.72***	-1.70***
	(0.137)	(0.143)	(0.136)
Share of small ruminants$^{\diamondsuit}$	0.06	0.08	0.10
	(0.351)	(0.361)	(0.361)
Share of female LS$^{\diamondsuit}$	-0.11	-0.17	-0.07
	(0.310)	(0.319)	(0.311)
Herd size in 2009$^{\diamondsuit}$	1.66***	1.82***	1.62***
	(0.358)	(0.403)	(0.322)
Experience and gender			
Parents of head were herders	-0.02	-0.03	-0.01
	(0.288)	(0.303)	(0.286)
Head always lived in current district	-0.44**	-0.43**	-0.43**
	(0.201)	(0.207)	(0.198)
Full-time herders	0.15**	0.15*	0.15**
	(0.074)	(0.077)	(0.074)
Volatility in LS population (dist.)	0.04	0.05	0.04
	(0.034)	(0.038)	(0.034)
Female head	-0.40	-0.42	-0.41
	(0.312)	(0.310)	(0.305)
Current idiosyncratic shocks			
Experienced idiosyncratic shock at t-1	-0.04	-0.06	-0.04
	(0.041)	(0.043)	(0.040)
Unexpected LS gains at t-1	0.02	0.04	0.01
	(0.051)	(0.047)	(0.052)
Unexpected LS losses at t-1[a]	-0.29***	-0.30***	-0.30***
	(0.029)	(0.030)	(0.029)
Loss covariance (distr.)		0.61	
		(1.023)	
Loss covariance*unexpected LS losses		0.58	
		(1.283)	
% of HHs with zero losses (distr.)			0.08
			(0.105)
Zero losses*unexpected LS losses			0.13*
			(0.069)
Period 2013/2014	0.13***	0.14***	0.14***
	(0.031)	(0.032)	(0.032)
Constant	-3.79***	-7.21***	-6.39***
	(1.066)	(1.766)	(1.431)
Household characteristics	YES	YES	YES
District characteristics	YES	YES	YES
Province and time FE	YES	YES	YES
Observations	1,526	1,474	1,526
Number of households	763	737	763

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. $^{\diamondsuit}$Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share of small ruminants. [a]In columns 3 and 4, household-level livestock mortality and unexpected livestock losses are demeaned for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table B.3: Compound annual livestock growth rates - 2010 to 2012/2015 (Hausman-Taylor estimator)

	Outcome: Livestock growth rates		
	(1)	(2)	(3)
Dzud intensity			
Livestock mortality in 2010 (hh) (log)[a]	-0.04*	-0.04	-0.06**
	(0.024)	(0.024)	(0.027)
Mortality covariance in 2010 (distr.)		0.36	
		(0.271)	
Morality covariance*livestock mortality (hh)		-0.20	
		(0.241)	
% of HHs with zero *dzud*-losses (distr.)			0.17
			(0.197)
Zero *dzud*-losses*livestock mortality (hh)			0.30***
			(0.110)
Beginning-of-year herd characteristics			
Herd size (log)[b◇]	-0.12***	-0.11***	-0.12***
	(0.020)	(0.020)	(0.020)
Share of small ruminants[◇]	0.08	0.08	0.08
	(0.141)	(0.141)	(0.142)
Share of female LS[◇]	-0.00	0.00	0.00
	(0.063)	(0.063)	(0.063)
Pre-shock herd size[◇]	0.09*	0.10*	0.11**
	(0.052)	(0.053)	(0.054)
Experience and gender			
Parents of head were herders	0.01	0.02	0.01
	(0.052)	(0.053)	(0.052)
Head always lived in current district	0.02	0.02	0.02
	(0.031)	(0.030)	(0.031)
Full-time herders	0.02	0.02	0.02
	(0.015)	(0.015)	(0.015)
Volatility in LS population (dist.)	0.01	0.01	0.01
	(0.005)	(0.005)	(0.005)
Female head	-0.10**	-0.09**	-0.10**
	(0.047)	(0.047)	(0.047)
Current idiosyncratic shocks			
Experienced idiosyncratic shock at t-1	-0.01	-0.01	-0.01
	(0.007)	(0.008)	(0.007)
Unexpected LS gains at t-1	-0.02	-0.02	-0.02
	(0.016)	(0.016)	(0.016)
Unexpected LS losses at t-1[a]	-0.01***	-0.01***	-0.01***
	(0.004)	(0.004)	(0.004)
Loss covariance (distr.)		0.12	
		(0.122)	
Loss covariance*unexpected LS losses		0.06	
		(0.098)	
% of HHs with zero losses (distr.)			-0.03
			(0.028)
Zero losses*unexpected LS losses			0.02*
			(0.013)
Period 2013/2014	0.00	0.00	-0.00
	(0.005)	(0.005)	(0.005)
Constant	-0.20	-0.41	-0.52*
	(0.222)	(0.296)	(0.312)
Household characteristics	YES	YES	YES
District characteristics	YES	YES	YES
Province and time FE	YES	YES	YES
Observations	1,706	1,706	1,706
Number of households	853	853	853

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. [◇]Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share of small ruminants. [a]In columns 3 and 4, household-level livestock mortality and unexpected livestock losses are demeaned for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table B.4: Annual livestock growth rates 2012-2015 (Hausman-Taylor estimator) - Alternative shock measures

	Outcome: Livestock growth rates					
	(1)	(2)	(3)	(4)	(5)	(6)
Dzud intensity						
Livestock mortality in 2010 (hh) (log)	-0.51***					
	(0.142)					
Livestock mortality in 2010 (hh) (%)						-1.03***
						(0.251)
Mortality <20%					-0.05	
					(0.129)	
Mortality 40-60%					-0.14	
					(0.103)	
Mortality 60-80%					-0.53***	
					(0.118)	
Mortality >80%					-0.99***	
					(0.247)	
Livestock mortality in 2010 (district) (%)		-1.30**				
		(0.596)				
Livestock mortality in 2010 (sub-district) (%)			-0.01			
			(0.447)			
Winter temperature (district)				-1.54**		
				(0.653)		
Winter temperature squared				-0.61**		
				(0.261)		
Beginning-of-year herd characteristics						
Herd size (log)[a]◊	-1.58***	-1.59***	-1.59***	-1.59***	-1.59***	-1.59***
	(0.111)	(0.109)	(0.109)	(0.109)	(0.109)	(0.109)
Share of small ruminants◊	-1.02	-1.00	-1.00	-1.01	-1.00	-1.00
	(0.778)	(0.767)	(0.767)	(0.766)	(0.767)	(0.767)
Share of female LS◊	-0.05	-0.09	-0.09	-0.09	-0.09	-0.09
	(0.320)	(0.315)	(0.316)	(0.316)	(0.315)	(0.315)
Herd size in 2009◊	1.22***	0.75***	0.76***	0.80***	0.64***	0.68***
	(0.270)	(0.156)	(0.156)	(0.165)	(0.141)	(0.143)
Experience and gender						
Parents of head were herders	0.03	-0.21	-0.23	-0.19	-0.19	-0.16
	(0.237)	(0.210)	(0.211)	(0.213)	(0.213)	(0.209)
Head always lived in current distr.	-0.10	-0.00	0.05	-0.00	0.01	0.02
	(0.153)	(0.127)	(0.131)	(0.134)	(0.127)	(0.128)
Full-time herders	0.13	0.13	0.13	0.13*	0.14*	0.13*
	(0.081)	(0.078)	(0.078)	(0.078)	(0.078)	(0.078)
Female head	-0.21	-0.28	-0.30	-0.29	-0.27	-0.25
	(0.225)	(0.220)	(0.219)	(0.220)	(0.206)	(0.210)
Volatility in LS population (distr.)	0.03	0.03	0.01	0.01	0.02	0.02
	(0.068)	(0.023)	(0.021)	(0.021)	(0.019)	(0.018)
Current idiosyncratic shocks						
Experienced idiosyncratic shock at t-1	0.01	0.00	0.00	0.00	0.00	0.00
	(0.034)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
Unexpected LS gains at t-1	-0.06	-0.05	-0.05	-0.05	-0.05	-0.05
	(0.048)	(0.045)	(0.046)	(0.046)	(0.045)	(0.045)
Unexpected LS losses at t-1	-0.17***	-0.17***	-0.17***	-0.18***	-0.17***	-0.17***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.017)	(0.018)
Period 2013/2014	0.08***	0.09***	0.08***	0.09***	0.08***	0.08***
	(0.024)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
Constant	-3.54**	-1.95**	-2.25**	-3.31***	-1.60*	-1.54*
	(1.423)	(0.951)	(0.976)	(1.184)	(0.882)	(0.867)
Household characteristics	YES	YES	YES	YES	YES	YES
District characteristics	YES	NO	YES	YES	YES	YES
Fixed Effects	Province	District	Province	Province	Province	Province
Time FE	YES	YES	YES	YES	YES	YES
Observations	1,710	1,710	1,710	1,710	1,710	1,710
Number of Households	855	855	855	855	855	855

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The excluded reference category in column 5 is losses between 20 and 40%. The same household and district controls as in table 2 are used. ◊Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share of small ruminants. [a]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table B.5: Annual livestock growth rates 2012-2015 (Hausman-Taylor estimator) - Additional robustness tests

	Outcome: Livestock growth rates		
	(1)	(2)	(3)
Dzud intensity			
Livestock mortality in 2010 (hh) (log)[a]	-0.56***	-0.50***	
	(0.141)	(0.130)	
Beginning-of-year herd characteristics			
Herd size (log)[a,b◊]	-1.59***	-1.55***	-1.59***
	(0.110)	(0.110)	(0.108)
Herd size*LS mortality (hh)		-0.12**	
		(0.058)	
Share of small ruminants[◊]	-1.01	-1.28*	-1.04
	(0.769)	(0.773)	(0.765)
Share of female LS[◊]	-0.08	-0.10	-0.10
	(0.315)	(0.316)	(0.315)
Herd size in 2009[◊]	1.16***	1.11***	
	(0.250)	(0.253)	
Experience and gender			
Parents of head were herders	-0.07	-0.08	
	(0.226)	(0.217)	
Head always lived in current district	0.03	0.04	
	(0.144)	(0.140)	
Full-time herders	-0.26	0.14*	0.15
	(0.305)	(0.079)	(0.096)
Full-time herder*LS mortality (hh)	0.09		
	(0.065)		
Female head	-0.23	-0.24	
	(0.221)	(0.216)	
Volatility in LS population (distr.)	0.03*	0.04**	
	(0.018)	(0.018)	
Current idiosyncratic shocks			
Experienced idiosyncratic shock at t-1	0.00	0.00	0.00
	(0.033)	(0.033)	(0.033)
Unexpected LS gains at t-1	-0.05	-0.06	-0.06
	(0.046)	(0.046)	(0.051)
Unexpected LS losses at t-1	-0.17***	-0.17***	-0.18***
	(0.018)	(0.018)	(0.017)
Period 2013/2014	0.08***	0.08***	0.07***
	(0.025)	(0.025)	(0.027)
Constant	-2.31**	-4.20***	0.97
	(1.029)	(1.467)	(0.652)
Household characteristics	YES	YES	YES
District characteristics	YES	YES	YES
Province and time FE	YES	YES	YES
Observations	1,710	1,710	1,710
R-squared			0.575
Number of households	855	855	855

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. [◊]Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share of small ruminants. [a]In column 2, household-level livestock mortality and beginning-of-year heard-size are demeaned for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table B.6: Livestock recovery to pre-shock levels (OLS)

	Outcome: Livestock recovery rate 2009-2014/15					
	(1)	(2)	(3)	(4)	(5)	(6)
Dzud intensity						
Livestock mortality in 2010 (hh) (log)	-0.15***	-0.14***				-0.10***
	(0.041)	(0.043)				(0.027)
Livestock mortality in 2010 (district) (%)			-0.54			
			(0.410)			
Livestock mortality in 2010 (sub-district) (%)				-0.48**		
				(0.220)		
Winter temperature (district)					-0.33	
					(0.336)	
Winter temperature squared					-0.24*	
					(0.121)	
Herd characteristics						
Share of female livestock	-0.90**	-1.00***	-0.92**	-0.98**	-1.02**	-0.31
	(0.433)	(0.378)	(0.464)	(0.436)	(0.453)	(0.252)
Share of small ruminants	1.11***	0.84***	1.04***	1.05***	1.08***	0.85***
	(0.235)	(0.205)	(0.245)	(0.235)	(0.232)	(0.152)
Herd size in 2009	-0.41***	-0.41***	-0.57***	-0.58***	-0.59***	-0.29***
	(0.103)	(0.081)	(0.117)	(0.113)	(0.114)	(0.054)
Experience and gender						
Parents of head were herders	0.22*	0.30**	0.18*	0.17*	0.21**	0.13
	(0.125)	(0.127)	(0.103)	(0.105)	(0.102)	(0.111)
Head always lived in current district	-0.01	-0.07	-0.05	-0.03	-0.03	0.05
	(0.094)	(0.105)	(0.093)	(0.092)	(0.094)	(0.076)
Full-time herders	0.30***	0.35***	0.30***	0.31***	0.33***	0.23***
	(0.078)	(0.080)	(0.077)	(0.077)	(0.080)	(0.066)
Female head	-0.20**	-0.07	-0.20**	-0.19**	-0.19**	-0.21***
	(0.092)	(0.097)	(0.095)	(0.095)	(0.095)	(0.080)
Volatility in LS population (distr.)	-0.01		-0.01	-0.01	-0.02	0.01
	(0.013)		(0.017)	(0.015)	(0.014)	(0.008)
Current idiosyncratic shocks						
Experienced idiosyncratic shock at t-1	-0.01	-0.03	-0.04	-0.04	-0.03	0.06
	(0.088)	(0.087)	(0.088)	(0.086)	(0.088)	(0.065)
Unexpected LS gains at t-1	0.06	-0.00	0.05	0.06	0.04	0.02
	(0.112)	(0.142)	(0.113)	(0.112)	(0.113)	(0.084)
Unexpected LS losses at t-1	0.10***	0.10***	0.11***	0.11***	0.12***	0.08***
	(0.023)	(0.022)	(0.025)	(0.024)	(0.025)	(0.021)
Shock coping in 2010						
Temporary migration						0.19***
						(0.069)
Sold livestock						0.06
						(0.067)
Household and district characteristics						
Education	0.16***	0.14**	0.18***	0.17***	0.19***	0.13**
	(0.057)	(0.057)	(0.057)	(0.057)	(0.056)	(0.053)
Location is rural	0.35***	0.32***	0.37***	0.35***	0.40***	0.30***
	(0.073)	(0.092)	(0.073)	(0.076)	(0.073)	(0.064)
Cellphone networks	-0.05		-0.03	-0.04	-0.01	-0.06**
	(0.034)		(0.034)	(0.034)	(0.036)	(0.028)
Number of transportation options	0.04		0.05	0.04	0.03	0.06
	(0.044)		(0.042)	(0.042)	(0.042)	(0.041)
Constant	2.82***	2.85***	3.33***	3.35***	3.30***	2.16***
	(0.535)	(0.490)	(0.531)	(0.544)	(0.700)	(0.301)
Household characteristics	YES	YES	YES	YES	YES	YES
District characteristics	YES	NO	YES	YES	YES	YES
Fixed Effects	Province	District	Province	Province	Province	Province
R-squared	0.242	0.346	0.229	0.229	0.235	0.295
Observations	871	871	871	871	871	860

Cross-sectional analysis based on wave 3. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table B.7: Livestock offtake 2012-2015 (Hausman-Taylor estimator) - Coping and emergency aid

	LS consumption			LS sales			newborns			LS purchases		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Livestock mortality in 2010 (hh) (log)	-0.10	-0.13**	-0.13**	-0.46**	-0.53***	-0.58***	-0.67***	-0.65***	-0.64***	-0.23	-0.17	-0.20*
	(0.064)	(0.053)	(0.050)	(0.220)	(0.169)	(0.165)	(0.245)	(0.205)	(0.145)	(0.168)	(0.131)	(0.111)
Temporary migration in 2010	0.49			1.41			-2.88			-0.92		
	(0.754)			(2.538)			(2.975)			(1.749)		
Temporary migration*LS mortality (hh)	-0.11			-0.13			0.48			0.14		
	(0.130)			(0.403)			(0.506)			(0.265)		
Livestock sold		-0.23			0.78			0.00			1.86	
		(1.507)			(5.482)			(2.049)			(4.201)	
Livestock sold*LS mortality (hh)		0.03			0.01			0.28			-0.27	
		(0.301)			(1.086)			(0.316)			(0.845)	
Amount of aid			0.48			0.59			1.01			-0.59
			(0.514)			(1.455)			(1.680)			(0.932)
Amount of aid*LS mortality (hh)			-0.75*			0.28			-0.70			-1.20
			(0.406)			(1.045)			(1.375)			(0.850)
Constant	-0.27	-0.56	-0.50	-6.63**	-7.64***	-7.98***	-7.61**	-6.69***	-6.46***	-2.59	-2.18	-2.01
	(0.733)	(0.610)	(0.567)	(2.789)	(2.195)	(1.985)	(3.149)	(2.071)	(1.650)	(1.977)	(1.724)	(1.398)
Household, herd and district characteristics	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province and time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,688	1,688	1,710	1,688	1,688	1,710	1,140	1,140	1,160	1,688	1,688	1,710
Number of households	844	844	855	844	844	855	570	570	580	844	844	855

Model estimated with the Hausman-Taylor estimator. Endogenous controls as in the baseline specification. In addition, temporary migration during the shock as well as livestock sold directly after the shock also defined as endogenous control. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
Household-level livestock mortality and the amount of external aid are demeaned for better interpretability of the interaction terms. Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, and MRCS emergency aid data.

Appendix C: Appendix for Chapter 4

List of variables included in the double machine-learning partialling-out estimation

All variables presented in the descriptive statistics (Table 4.1) have been included in the LASSO estimation of market income and education. For the estimation, I transformed assets into a standardized asset value and used the dependency ratio instead of the number of supported children. The particular estimation method is the LARS (least angle regression), the LASSO approach for linear models (Efron et al., 2004). I included the set of covariates that minimized the C_p statistic (similar to an AIC) for the partialling-out regressions. For the cross-validation, the sample was split into two groups.

Based on the results from the LASSO estimation, the coefficient vector X for the market income partialling-out regression contains:

$$
\begin{aligned}
X = \{ & credit\ constraints, standardized\ asset\ value, female, patience\ (standardized), \\
& financial\ literacy, selling\ food, risk\ aversion\ (standardized), \\
& also\ vending\ on\ other\ markets, community\ groups, district\ FE, business\ log, \\
& business\ formally\ registered, market\ income\ share\ in\ total\ income, \\
& main\ material\ of\ the\ wall\ is\ bricks, farming, whether\ some\ friends\ are\ vendors, \\
& distance\ to\ the\ market >= 30 minutes, relative\ wealth\ (standardized), literacy, \\
& numeracy, experience, experience\ squared, paying\ taxes \}
\end{aligned}
$$

Similarly, the coefficient vector X for the education partialling-out regression contains:

$$
\begin{aligned}
X = \{ & literacy, business\ log, age, dependency\ ratio, credit\ constraints, \\
& female, business\ formally\ registered, experience, experience\ squared, \\
& also\ vending\ on\ other\ markets, district\ FE, community\ groups, \\
& respondent\ is\ main\ contributor\ to\ HH\ income, household\ size, \\
& distance\ to\ the\ market >= 30 minutes, farming, standardized\ asset\ value, numeracy, \\
& more\ than\ one\ job, main\ material\ of\ the\ wall\ is\ bricks, financial\ literacy, \\
& risk\ aversion\ (standardized), farming \}
\end{aligned}
$$

Publications

Chapter 2: Food Intake and the Role of Food Self-Provisioning (with Kati Krähnert)

- The Journal of Development Studies 53:8, 1303-1322, http://dx.doi.org/10.1080/00220388.2016.1228881.
- DIW Discussion Paper 1537 (2015).
- Part of this research also contributed to the DIW RoundUp 69 (2015) "Die langfristigen Folgen von Mangel- und Unterernährung in Entwicklungsländern" (single-authored).

Chapter 3: When Shocks Become Persistent: Household-Level Asset Growth in the Aftermath of an Extreme Weather Event (with Kati Krähnert)

- DIW Discussion Paper 1759 (2018).

Statement

I testify through my signature that all information that I have provided about resources used in the writing of my doctoral thesis, about the resources and support provided to me as well as in earlier assessments of my doctoral thesis correspond in every aspect to the truth.

Berlin, February 2, 2021

. . . .

Anna Katharina Lehmann-Uschner